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Fundamentals of

ECONOMIC GEOGRAPHY

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NELS A. BENGTSON, *Consulting Editor*

FUNDAMENTALS
OF
ECONOMIC GEOGRAPHY

by

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PREFACE

THE THIRD EDITION MAINTAINS THE THESIS OF EARLIER EDITIONS THAT ALL students should acquire an understanding of the resources at man's disposal and the natural conditions under which their utilization may be achieved. This thesis is more pertinent than ever in the world of today wherein all countries are near neighbors and where economic events in one country may, and usually do, have repercussions in many others. While an understanding of the nature of natural resources and the conditions that affect their utilization is paramount to all thoughtful citizens, it is particularly important to those whose future fields of activity may be in the broader aspects of business or politics, as well as to those who aspire to become professionals in such fields as economics, sociology, history, or law.

Modern geography is partly a physical and partly a social science. It seeks, among other things, to relate facts of the natural environment to facts and problems of the socio-economic environment. In this respect geography is one of the few sciences that attempts to bridge the apparently widening gap between the physical and the social sciences. Its position, although a difficult one, is of rapidly increasing importance in the modern world. Economic geography is a subdivision of social geography in the broadest sense.

Economic geography investigates the diversity of basic resources and of major productive activities of the different parts of the world. It tries to evaluate the effects that differences in physical environment have upon utilization of these resources. It studies differences in basic economic development in various regions or countries of the world, as well as the nature of the trade which may result from this differential development. As is true of any science, economic geography is partly descriptive and classificatory; but its major function is to analyze, correlate, and interpret. It may deal with a specific economic-geographic problem over a large area, or it may treat the interrelated economic-geographic problems of a small region.

This book has been written primarily for students from the freshman to the senior year. The phraseology, we trust, is clear and accurate and not unnecessarily technical. While the book is not intended for the specialist in geography, we hope that the geographic approach to the complex problems of utilization of natural resources, including the problems of their conservation, will be of interest to professionals in related fields, and to others who wish to have a realistic approach to today's world problems.

Since the main purpose of the book is to aid students in developing an understanding of the fundamentals of economic geography, a few chapters are included which belong essentially under the heading of physical geography. Even these, however, are oriented to their economic significance. The authors, after long experience in college teaching, are convinced that most students profit by a brief exposition of the facts and principles of physical geography that are basic to the study of economic geography.

While in essence this book is a general economic geography, the effects of climatic and other physical conditions upon distribution of the world's agricultural production are so pronounced that, for purposes of comparison, it was found advantageous to base the chapters dealing with agricultural resources and activities upon a limited number of large-scale climatic regions.

In the introductory chapter the authors have set forth the general objectives of economic geography. These objectives imply a knowledge of fundamental geographic facts, conditions, and principles that affect the processes whereby the peoples of the earth make their living. While they must necessarily be considered from the viewpoints of varying individual levels of living, they must also be considered from the point of view of group living, for man lives not for and by himself alone. Therefore, first attention is given to the distribution of population over the earth, raising not only the question of where the majority of the world's peoples live, but also why they live there and what changes in this distribution may occur in the foreseeable future.

The introductory chapters are followed by others that deal with the general aspects of the earth surface, such as land forms mineral resources, and soils, particularly in their relation to land use. These are followed by chapters that discuss the major climatic regions of the world from the point of view of general production capacities and specific production possibilities, with emphasis upon physical and other causes of similarities and differences. In this manner the geography of the world's agriculture in its relation to worldwide well-being is brought into clear focus.

The third division of the book emphasizes the mineral resources which man uses to produce the tools of production as well as many consumption goods. Here are treated the rocks and minerals which serve as raw materials in nature's processes of soil formation and with which man builds structures and machines. Under this heading come the power resources which serve as the basis for modern industrialization, together with the fashioning of metals into forms whereby power can be harnessed and put to productive use. In these chapters attention is called to the fact that through the use of natural power resources modern industry attains high per capita production, thus making possible high standards of living. Man, whose expenditure of energy was formerly the chief source of power for the production of goods, has become a director instead of a source of power.

The fourth division emphasizes manufacturing and commerce, the two processes whereby goods are made and widely exchanged for the benefit of an ever-increasing proportion of the world's population.

Throughout the discussion emphasis is put upon the fact that maintenance of present high standards of living depends upon wise use of resources. Conservation implies such use. It maintains that waste, physical or economic, is inexcusable, but it does not advocate withholding resources from utilization. The principles of conservation of natural resources apply most obviously to soils, petroleum, natural gas, coal, the metallic minerals, and forest resources, but it should be understood that they apply to human resources as well.

The authors have tried throughout this volume to focus students' attention upon a general objective, *to think upon a basis of fact.* To use facts as a basis of thinking rather than as mere items of memory provides incentive toward development of habits of thought that will endure. This is an educational objective of highest significance. "Study without thought is wasteful. Thought without study is dangerous." (Confucius)

NELS A. BENGTSON
WILLIAM VAN ROYEN

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Nels A. Bengtson
William Van Royen

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Fundamentals of

ECONOMIC GEOGRAPHY

Chapter One

THE FIELD AND FUNCTION OF ECONOMIC GEOGRAPHY

MAN HAS BEEN THE SLAVE OF HIS material needs for untold generations. This is true especially in those parts of the world where Nature was niggardly in her production of natural substances directly suitable for food, and where the existence of a winter season necessitated protection against cold and provision against seasonal deficiencies in food production. The idyllic life of the proverbial South Sea island, where throughout the year food is available merely for the harvesting, where clothing is essentially decoration and shelter needs to be little more than a roof, where there is an abundance of time for play, song, laughter, and the exercise of all the artistic talents, has been possible only in a few of the world's most favored spots. Even there it was possible only so long as people did not become too numerous. Everywhere else man has had to go at the business of making a living for himself and his dependents in dead earnest. In many parts of the world this business was grim indeed, frequently involving physical effort from sun to sun.

In all cases man had to make this living by applying labor—most of it physical, some of it mental—to the resources at hand. Natural resources occur everywhere in varying kinds, quantities, and qualities, but hardly any are available and ready for instant use and are so abundant—such as air—that they constitute free goods. Most of them are found in limited quantities and acquire utility—or become "utilities" in economic parlance—only as man exploits them, that is, makes them available and suitable for the satisfaction of human desires. Only thus may resources become real economic goods or wealth.

Unused resources are not real wealth, but merely potential sources of wealth. For thousands of years the vast coal deposits of North America did not constitute wealth to the native inhabitants, and even at present part of these deposits do not constitute wealth, as they may be undeveloped, or may be too deep for present successful exploitation. However, if unused resources are recognized as potential sources of wealth, they may be exchanged for economic goods, and thus acquire value.

The creation of wealth—production—is based upon man's utilization of natural resources. As nearly all of these resources are limited in quantity and some are of mediocre quality, and as the total number of inhabitants of this world is increasing rapidly, notwithstanding modern wars, it is highly desirable that such utilization be as efficient as possible with a minimum of waste of the resource involved and of needed energy.

Comfortable living based upon an optimum per capita wealth for the entire population of a region is largely a function of available resources, man's ingenuity in adapting them to his own use, the physical energy at his disposal, and the total number of people whose desires have to be satisfied. Since the prior satisfaction of certain material needs is indispensable to the development of many of man's higher capacities, material production is basic to the existence of all types of society, primitive as well as modern, simple as well as complex.

However, man, depending on his own physical power for the necessary acquisition and transformation of raw materials, even supplemented by the power of domesticated animals or the small-scale use of water or wind, can produce only at a slow rate and in small quantities. Thus, for thousands of years he could eat his bread only by the sweat of his brow. The average man was never far from a marginal to submarginal mode of existence; his worldly possessions were few, his moments of leisure were brief and rare. Before the so-called industrial era, agriculture was by far the most common occupation in the world and the source of a large proportion of the wealth. In fact, individual wealth could generally be amassed most successfully by large, landed proprietors.

Since no ordinary person could produce much above his own basic needs for subsistence purposes, there had to be a large number of primary producers. Methods of manufacture were simple and laborious. Though the quality of the manufactured goods frequently was high—sometimes considerably higher than that of modern machine-made products—the quantities produced were small. Thus the amount of manufactured goods available per capita was small, and, comparatively speaking, prices for manufactured goods were high. Each community was nearly self-sufficient, because it could not demand and did not feel the need for many outside products.

Power and production. In order that the average man may live well, and have comforts, leisure, and even a few luxuries at his disposal, not only are large amounts of transformable materials necessary, but the production processes must be carried on with the aid of much power and at a rapid rate. This is especially true where people are numerous and where Nature forces higher minimum needs on man, as in the middle and higher latitudes.

The human efforts, physical and mental, which are directed toward the production of goods and services, we commonly call *labor*. As a result of man's technical progress, labor now can be supplemented by natural power resources—huge stores of energy which were practically unused during the ages prior to the nineteenth century. Through the use of coal, petroleum, natural gas, and hydro-electrically harnessed falling water, every average American family has at its disposal, indirectly and directly, the equivalent of 120 theoretical horses working 8 hours a day, 6 days a week.[1]

In the factory. Because of these power resources, it has been possible to reduce the working hours for industrial employees in this country from 12 or 14 hours a day to 8 hours, and in some cases to only 6 hours a day.

The extensive use of power, applied through an enormous variety of machinery, permits high specialization of tasks. Although this specialization results in certain evident disadvantages for the individual as well as for society as a whole, it also results in production of greater surpluses which may be exchanged, through the medium of money, for the diversity of things implied in the expression "a high standard of living." Notwithstanding the decrease in working hours, the daily wage has not suffered. The worker receives more in real wages for his 6 to 8 hour day now than did his predecessor of Revolutionary times for his 14 hours of toil. The workers in the mills and factories have, on the whole, better working conditions than they ever had before, and they enjoy luxuries in food, clothing, and recreation such as were unattainable for most people before the industrial era.

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[1] *Energy Resources and National Policy.* Report of the Energy Resources Committee to the National Resources Committee, Washington, D. C., 1939, p. 8.

On the farms. Large-scale use of power has greatly simplified many of the onerous tasks of farming. The advent of the automobile and the truck brought a great saving of the time formerly spent in hauling products by means of horse-drawn vehicles. However, the most fundamental change in this country, and what may be said to amount to the *first real agricultural revolution* in the history of civilization, did not come until the middle nineteen-twenties and the early thirties, with the invention of the general-purpose or row-crop tractor with power take-off, power-lift, and low-pressure pneumatic tires.

Up to the end of 1938 about seven and a half million horses had been displaced in this country by power equipment, probably five million of them by tractors. Between the end of 1938 and the beginning of 1947 there was another decrease in the number of work horses of approximately 4,600,000. It is estimated that there is a saving of about 65 hours a year in labor needed for each horse displaced by tractor power, and that the average number of horses displaced per tractor is about 4.4. Thus it can be seen that by substituting tractors for horses the total reduction in labor utilized in maintenance of farm-power units runs into the hundreds of millions of man-hours. Besides, it is estimated that the average tractor saves 850 man-hours per year on all kinds of work needed on the farm. The number of tractors on farms in the United States has increased from 920,000 in 1930 to 3,150,000 on January 1, 1948. The real agricultural revolution is upon us!

Power, transportation, and economic distance. As long as horse-drawn carriages or wind-propelled ships were the fastest modes of travel and freightage, the earth seemed large. Places a few hundred miles away were remote, and only nonperishable goods of high value could be exchanged. All transportation was slow, and land transportation was both slow and costly. World markets for the agricultural products of interior lands were out of the question, and only products that would not easily spoil could be shipped by sea. Production of most goods needed by man was in close proximity to the places of consumption. Supplies of foods and raw materials consisted chiefly of what was locally available.

The world consisted essentially of a large number of small, nearly closed regional economics. With the development of rapid means of transportation and communication, all this has been changed. Express trains, steamships, trucks, automobiles, airplanes, telephones, and radios have brought changes more revolutionary than most of us realize. Though its miles remain unchanged, the world has indeed become small. From the viewpoints of trade, communication, and politics its size is but a fraction of what it was in the days of Washington and Jefferson. Then, the voyage across the Atlantic involved weeks and sometimes months of discomfort; now, it can be made by airplane in less than a day. The changes have made all continents into close neighbors instead of areas of little concern to one another because of unbridged distance.

Factors of production. The relatively high standards of living which have been characteristic of the so-called industrial countries under peacetime conditions are the results of man's use of the machine, whereby he employs for productive purposes the energy of coal, petroleum, natural gas, and falling water. By utilizing and directing this energy through the machine, man has been able to produce tremendous quantities of goods, in contrast with his low per capita productivity of a century and a half ago. The use of natural energy also has enabled him to move himself and especially his goods fast and far, in comparison with the snail's pace of former centuries. Because of these circumstances the changes in the modes of living which have come to the people of the United States and other industrial countries have been far-reaching and profound.

In our modern industrial economy, instead of having to deal with the four classical factors of production—natural resources ("land" of the economists), labor, capital, and entrepreneurship—we really should take into account five factors: (1) those natural resources which we transform into consumer and capital goods, including land; (2) power derived from natural resources; (3) capital goods; (4) labor; and (5) management. The tremendous amounts of natural energy which man has learned to tap have made possible both the construction and the extensive use of ever larger and more ingenious machinery, thus greatly expanding the role played by capital goods in our modern economy.

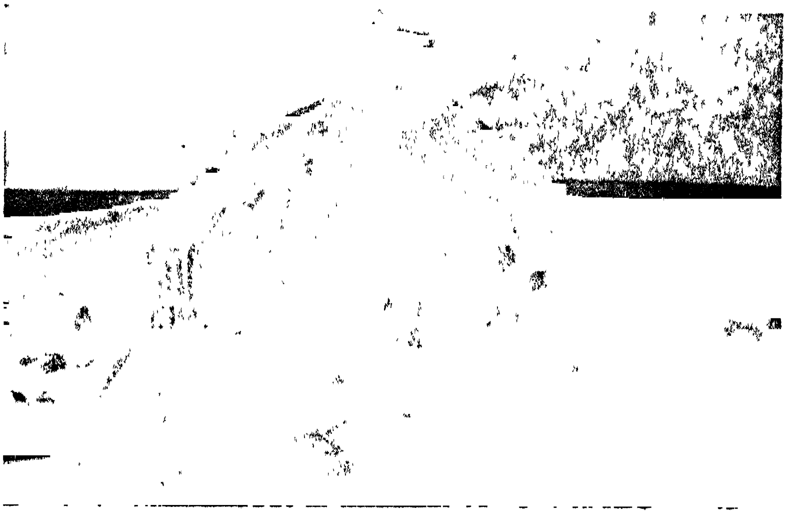
The importance of natural resources. Machines have been known for hundreds of years. The Romans knew and constructed machinery. Machinery was used during the Middle Ages and succeeding centuries before the so-called "industrial revolution." What is new is the use of power, first through the use of wind and wood, later through that of coal, oil, gas, and, in the near future, perhaps atomic energy. This use of *natural* power has made it possible to create our modern type of economy, which is essentially a "power-machine" economy. For the creation of the complicated capital equipment it needs, and for the ever more complex consumers goods it produces, not only large quantities of resources are needed, but also an ever increasing variety of resources.

The subject of economics deals primarily with three important phases of everyday life: (1) production, the creation of economic goods; (2) the distribution of economic goods; and (3) the mechanism of exchange of goods for goods. This latter phase, in its multifarious aspects such as value, media of exchange, prices, and the working of laws of supply and demand under varying market conditions, has had a great part of the attention of students of economics. But since the problems of production are more basic, they are becoming more pressing as a result of increasing specialization of production and the rapid increase in the total population of the world. Basic to production are resources, of many kinds and of varying qualities, and these are affected in many ways by the natural conditions under which they occur. Thus, a study of resources from the economic geographic point of view—that is, taking into account their distribution as well as the numerous ways in which the natural environment affects their quality and their usefulness—is basic to any thorough understanding of modern economics and modern economic problems.

Man and the natural environment. So great has man's technical progress been during the last one hundred and fifty years, so much has his insight into Nature deepened and his ability to utilize Nature increased, that he is sometimes inclined to the belief that his ingenuity has finally given him the whip hand and that the physical environment is at present something of secondary importance, something essentially passive and existent only to serve him as he sees fit. While it is, of course, foolish to believe that Nature ever determined man's mode of life in the strict sense of the word, it is equally foolish to believe that modern man through his high technical development has become independent of Nature. Witness the recurrent activity of our major and minor "dust bowls." Witness our rapidly silting reservoirs, the difficulties we have with our river floods, and our inability significantly to "improve" our weather and climate. Notwithstanding all the artificialities of modern life especially modern urban life, man and his various activities can never escape the direct or indirect limiting effects of the natural environment—and we use the term here in its broadest sense.

The importance of a differentiated natural environment. If the natural environment were uniform throughout the world; if there were no differences in relief, rocks, soils, climate, natural vegetation and crops; if power, metal, and other resources were equally distributed throughout; then the production of material goods, particularly in our modern power-machine economy, which must draw on so many different substances, would be infinitely simpler. Although physically such a "world without geography" would be of deadly monotony, economics and other social sciences would have the advantage of being able to concern themselves only with the problems resulting from the nonhomogeneity of human material and the general problems of efficiency of production. The sciences of society would be simpler, the problems of society might be slightly easier of solution. However, as things are, with profound regional differences in the natural environment, none of the social sciences can afford to ignore or treat lightly the basic geographic realities.

Differences in kinds of production and productive activities. Illustrations of differences in kinds of production and economic activities due to basic differences in the physical environment are so numerous and varied that no brief list of examples can reflect the diversity of existing conditions. A striking illustration is the Eskimo, because his life is so different (Illus. below). He must live under conditions which do not allow for sedentary crop agriculture. He eats mostly the meat of wild animals, blubber and fish, occasionally supplemented by berries and leaves. He must have a sturdy dog team and sledge to obtain these supplies, as well as the raw materials for the rather elaborate fur and skin clothing which must protect him against the low temperatures of the long Arctic winter. And every fall an igloo or stone house needs to be constructed or reconstructed with considerable care and ingenuity so as to shelter the family against the winter storms. Nevertheless, even here the environment does not entirely dictate man's economic activities. In the Eurasian Arctic, tribes living under fairly similar conditions have succeeded in taming the reindeer and exploiting the grazing resources of the Arctic lands in such a manner that their life is somewhat less hazardous than is that of the Eskimos.


Courtesy Lomen Brothers, Nome, Alaska.

Life in the Arctic. Siberian Eskimos in front of their summer dwelling

The forest Negro of Africa lives in an apparently much friendlier environment. Temperatures are such the year around that needs for clothing are at a minimum. Such clothing as is worn often constitutes more protection against insects than against the elements. Similarly the needs for adequate shelter are much less compelling. A good roof overhead as protection against the beating tropical rains is perhaps the prime necessity and is easily constructed with a variety of Nature's materials (Illus. below). The growing season may last all year, or at least as long as rainfall is sufficient, and tillage agriculture can be carried on with relatively little effort. While the hunt may provide supplementary animal food, the staff of life consists of plant foods. Life appears much easier, but the tropical climate is often debilitating, and diseases may take a heavy toll, thus creating serious obstacles against a more efficient use of the available resources. However, modern tropical medicine and modern sanitation are doing much, and may do still more to make life in the tropics less subject to the ravages of disease. For example, yellow fever, once the scourge of the American tropics, has been nearly eradicated.

Courtesy Agence Economique de l'Afrique Occidentale Française.

Life in the Tropics A Negro village in the northern Sudan

The physical environment does *not determine* the economic activity and the mode of life of man. In the Great Plains area, for example, the prehistoric Indians were semi-sedentary agriculturalists, the Indians of historic times were mostly nomadic hunters after their acquisition of the horse, and in the same environment the white man is primarily a sedentary agriculturalist although he carries on a multitude of other economic activities. Still, basic differences in the physical environment cannot be wiped out even by the advance over the earth of the modern power-machine economy. The modes of life of the nomadic Arab of the Near East, the *fellahin* of the Nile delta, the wheat farmer of the High Plains, the fisherman of Norway, the longshoreman of New York, the factory worker of Detroit or Pittsburgh, or the coffee grower of Brazil will never be the same. In each case the physical environment, though it does not determine a man's activities, puts certain limits upon the types of things he can produce and the kinds of economic activities in which he can successfully engage.

Indirectly, through differences in economic activities and modes of life, differences in the natural environment may even contribute to fundamental differences in thoughts, ideals, and character.

The Norwegians, for example, are noted for their vigor and thrift as well as for their prowess in seamanship. In Norway, a country of mountain ruggedness with thin and stony soil and a short growing season, the people must face an unusually difficult problem in making a living upon the land. The adjacent sea has been friendlier than the land, and consequently along the west coast numerous Norwegians have turned to it (Illus. above). For success, however, the sea has demanded courage, strength, and alertness. Thus, through the centuries, the stern requirements of life in this northern land have had their effects upon the inhabitants, only those who could meet them having survived. The Norwegians of today—virile, agile, alert, and sincere—have been influenced as a regional group by many of the factors of the physical environment.

In southern Europe are a people, the Spaniards, whose mode of life and trends of thinking are quite different. The contrasts in the activities and characteristics of the Norwegians and the Spaniards are due to a complexity of factors, but among these the importance of a different physical environment and the availability of different resources cannot be denied. The Spaniard of the most favored parts of the country—the productive districts of the southern regions —is quite different from his brother of the bleak Castilian plateau. The fertile and sunny coastal plains and valleys have always yielded abundant produce and have lacked the sternness with which Nature has faced the Castilian.

Photo by N. A. B.

Aalesund, Norway. An important commercial center and the home of a large fishing fleet. The ruggedness of the coastline leaves but little room for business blocks and residences.

But one need not go to distant lands to gather examples of important cultural differences that stem from differences in economic activities. The business heads and clerks who work in the financial district of New York City may speak glibly of "margins," "soft markets," "accept profits," and "stop-loss orders"—terms which must sound ominous and mysterious to the corn farmers of Iowa. Yet the Iowa farmers are keen judges of soil, pigs, and cows and are as expert on farm practices as some New Yorkers are on stock-market activities. The sugar planters of Louisiana live in a world quite unlike that of the sheepherders of Wyoming or the coal miners of Pennsylvania. In each case differences in environment lead to differences in activities and products, and often to differences in culture.

Differences in capacity of production. Differences are not limited to kinds of production; there are varying capacities of production as well. Some areas have great actual or potential productive capacity; others have but little, even with the aid of all the most modern means of exploiting the natural resources and modifying the natural landscape. To some extent these differences are expressed in the great extremes in density of population throughout the world. Sharp contrasts in density of population are the rule rather than the exception. Parts of Britain, France, Belgium, the Netherlands, and Germany, well-endowed with good soils, a suitable climate, large power and other resources have densities of population which range from 125 inhabitants per square mile to over 700 per square mile. Northern Finland and northern Russia, with poor soils, a short growing season, few suitable crops, and large forests show less than ten inhabitants per square mile. Except perhaps for limited areas, they will never equal in population density the better parts of western Europe. The plains of Romania, with good soils but frequent droughts, will probably never be able to support as dense an agricultural population as will parts of the Netherlands and Belgium, where the soils may not be quite so fertile, but where the climate is more dependable and thus agricultural productivity is higher. On the other hand, the island of Java, which is well-watered, fertile, and can produce two or even three crops per year because of its year-round growing season, is able to support a greater density of agrarian population than are the Low Countries. Still greater densities can be supported by industrial districts such as the Ruhr, northern France, central Belgium, and the British industrial districts.

In Asia, China proper resembles a beehive in its population density, while the deserts and semideserts of Mongolia and Sinkiang and the highlands of Tibet are open, empty spaces. In Africa, the lower Nile Valley presents a striking contrast in population with the near-by Libyan and Nubian deserts.

In North America millions of people are crowded into the great industrial areas of the east, while the arid west has extensive areas where people dwell miles apart (674 per square mile in Rhode Island, 1 in Nevada). Although contrasts in population density may be due to many causes, fundamental differences in the natural environment rank among the most important.

Differences in technical development. High standards of living are not by any means universal. The changes in mode of living and the general rise in the standard of living that have come to the people of the United States and the other industrial nations using large power resources and modern machinery have as yet been only slightly characteristic of many other parts of the world. Over much of the earth people are still living about as they have lived for centuries past, clinging precariously to old, often primitive methods of production, performing the same tasks, thinking the same thoughts, spurred to the same types of action by the same hopes and fears as their forebears. Such conditions, where the machine is virtually unknown, exist not only for the inhabitants of the African forest, the savanna, or along the rim of the world's deserts, or among millions of people in India and China, but even in parts of our own Appalachian Mountains. The final conquest of the earth by the power-machine economy is yet to come, and if and when it does come, it may greatly alter the present economic pattern of the world and the existing distribution of population. These future patterns will probably be nearly as irregular as the extremely irregular distribution patterns of most of the basic natural resources.

Increased exchange possibilities. Changes of technique have affected tremendously the whole social structure. The industrial nations have felt the influences most profoundly, but nearly all peoples of the earth have been affected in some degree. Only a small percentage of those living in almost complete isolation, such as some of the Indian tribes of the Amazon basin, the Papuans of interior New Guinea, or some of the Arctic Eskimos, remain virtually untouched. Now the world is small. Ideas are exchanged with almost incredible swiftness. The telegraph, the telephone, and the radio convey news to all parts of the world in fewer minutes than the number of months formerly necessary. Major events in any country are known in all other countries almost as soon as they occur. The progress in the exchange of goods has been almost as revolutionary as the progress in communication. The diner in New York may eat head lettuce from the Imperial Valley, bananas from Honduras, or papaya from Puerto Rico at the same meal at which he drinks coffee from Brazil or tea from India.

Specialization of human activities. Differentiation of activities is an outstanding characteristic of the present age. Instead of one man doing many things and being inefficient in most of them, one man does some one thing or manages some one line of activity and does that well. Tremendously increased energies available for power have increased the per capita production manifoldly. Individuals, communities, and states have ceased, though often grudgingly and with frequent relapses, to hold to the ancient idea of self-sufficiency, and, in so far as they have not been limited by artificial, restrictive measures, have tended to become efficient surplus producers of a few things, while satisfying other wants by exchange for the surplus products of other regions. On a world basis, a sufficiency of every commodity essential to human life seems possible if world population does not increase too rapidly and if population be distributed more in accordance with the economic potentialities of the different parts of the world than is the case at present.

It will always be true that certain items can be produced more advantageously in some regions than in others, and that some regions will have a surplus of a commodity, while others will have a deficit or may not be able to produce it at all. A much greater degree of regional specialization in the world than is possible at present under the dense web of tariffs, quota, financial, and other trade restrictions, would redound to the benefit of all inhabitants of the world. In fact, such specialization is necessary if the world is to be able to feed and support all its inhabitants in a decent manner. The fulfillment of this need will depend not only upon modern transportation facilities, but also upon the efficacy of international social and economic organization.

The importance of geographic studies. The economies of regions or countries are created by man and are therefore affected by numerous human factors. However, they are conditioned to varying degrees by the facts of the physical environment: by regional differences in that environment, by differences in the distribution and qualities of the natural resources, and by such differences in the capacity of production as are due to the natural environment. While the effectiveness of such influences usually is clear in the case of agrarian regions, or of industrial regions utilizing predominantly local raw materials, in other cases it may not be quite so clear. For example, even such apparently completely man-made regions as Greater London or Greater New

York could not exist without the easy accessibility conferred upon them by the physical environment and further improved by man. It may be truthfully said that no analysis of the economic life of a region can have validity unless it explores thoroughly the geographic facts and factors. Some of these facts and factors are physical in nature. A basic understanding of the physical environment remains an essential condition for a correct appreciation of the economic and social superstructure, notwithstanding the highly developed technical skills of modern man—in final analysis he still must live off and with Nature.

Modern geography is in part a physical science, in part a social science. As, among other things, it attempts to relate facts of the physical environment to those of the social environment, it is one of the few sciences which tries to bridge the apparently widening gap between the two great groups of the physical and the social sciences. Its position is a difficult one, but an extremely important one.

Physical geography embraces studies of cartography, the elements of weather, climatology, land forms or morphology of the land, water bodies and drainage, soils, natural vegetation, and animal life. *Social* or *human geography* embraces economic geography, social geography in the strict sense of the word, political geography, historical geography, and certain other phases of geography.

Economic geography investigates the diversity in basic resources of the different parts of the world. It tries to evaluate the effects that differences in the physical environment have upon the utilization of these resources. It studies differences in economic development in different regions or countries of the world. It studies transportation, trade routes, and trade resulting from this differential development and as affected by the physical environment.

The problems of progress. Industrial civilization of today depends upon the utilization of power and mineral resources. These resources are the keynotes to efficient production. Through them, if rightly used, the world can progress from scarcity to measured abundance, from poverty to relative prosperity. Wrongly used, for militaristic purposes, these resources can completely wreck all that man has achieved thus far. Through them leisure can be made possible. Rightly used, this leisure may give opportunity for the development of a fine type of culture; wrongly used, leisure and luxury may become forces leading ultimately to the decay and destruction of civilization.

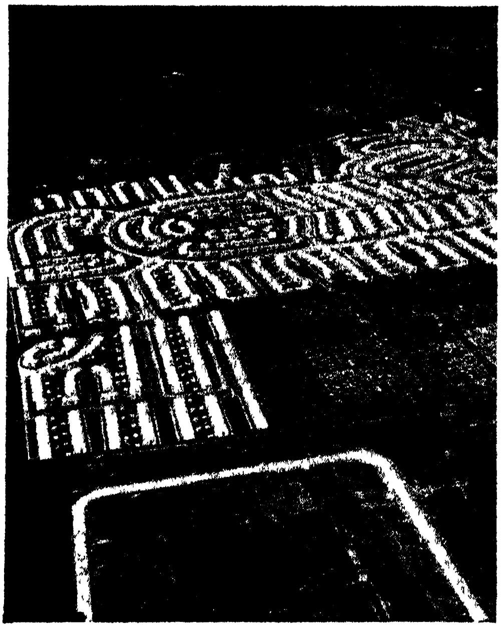
The best use of resources is—or, at least, should be, the basis of all modern economic activity, especially in view of the rapid increase of the population of the world. It requires a sound understanding of the nature of national resources, of the various factors of the natural environment and their relationships to various types of economies in the world. The goal of economic geography is to contribute effectively toward such understanding. It should lead the student to become a more efficient worker in the economic realm and, more important, it should enable him to meet more intelligently the problems of citizenship.

Chapter Two

DISTRIBUTION OF POPULATION

"THE MOST STRIKING FACT ABOUT population distribution is its great unevenness. In some places people live so crowded together that we are inclined to wonder how they can be comfortable, while in other places they are so widely scattered that the isolation might appear depressing. The density of population varies from that of Manhattan Island, Great Britain, or the teeming lowlands of eastern China, to that of the vast, sparsely peopled expanses of northern Canada or the Amazon lowlands." Such contrasts raise questions: "Just how is mankind distributed? Why is the distribution so uneven? Is this unevenness a permanent feature of human geography or will the people gradually spread out evenly? Are the differences in density increasing? Are some areas growing in population while others are declining? And what do these differences mean to us?"

Personal meaning of various densities. Figures of population density will have more significance if you will try to imagine how you personally would feel living under various conditions. Do you live in a crowded section of a city? In a suburb? In a small town or village? On an intensively cultivated small truck farm? Or out in the great open spaces on a ranch? Do you live in an apartment with neighbors on three sides of you, above, and below, as on Manhattan Island (population density 85,836 per square mile)? (Illus. p. 20.) Or do you live in the suburbs where there is a house for each family and a plot of ground for lawn and garden around each house? (Illus. below.) Are you on a ranch in Montana (density, including towns, 4 per square mile), where your nearest neighbor



Courtesy British Information Service.

Suburban housing at Great Yarmouth, southeastern England. Cottages prefabricated of steel frameworks and concrete slab walls to conserve wood which has to be imported. This project was completed in 1947 as a partial answer to the wartime damage of homes in Britain.

may be several miles away. (Illus. p. 14.) The differences in mode of living suggested by these questions affect the economic activities, the social practices, and the whole outlook upon life of the individuals concerned. The ranchman can hardly be expected to understand fully the economic problems or to have the social viewpoint of the man who lives in the congested city. Nor can the urbanite be expected to understand fully the environment, economic problems, and social conditions that confront the ranchman on the plains. Nevertheless, we all are one nation, and citizens of the same world, and to live in peace we must try to have some common understanding.

Advantages and disadvantages of dense population. People who live close together usually form a wider circle of acquaintances than do people who live in areas of sparseness. Under such conditions, men who have more than ordinary initiative are likely to become leaders of groups and parties. This development of a spirit of group activity or teamwork, and the development of individuals into leaders, are commonly classed among the most important results of dense population. It is understandable that much of the political, social, and religious leadership of today comes from the city.

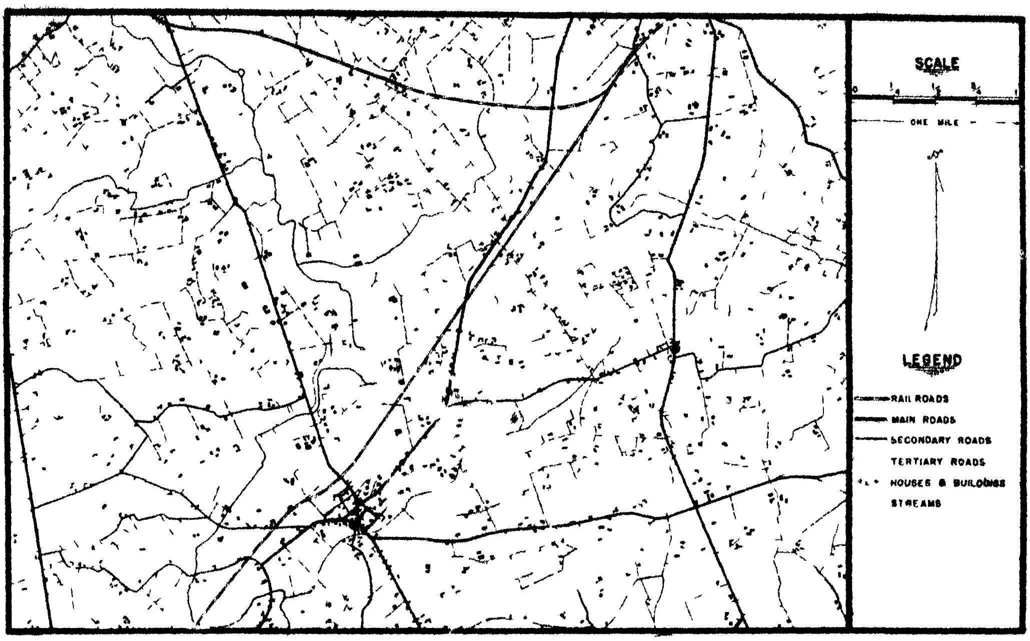
The ready exchange of ideas encourages some types of literary and scientific development. The existence of a large compact market favors division of labor and attracts outstanding specialists in many fields. Nearly everyone, whatever his interest or ideas, can find like-minded people in a large city. Furthermore, dense populations are likely to have an aggregate wealth that promotes educational, medical, and social facilities. Modern utilities—electricity, gas, and sometimes even central steam plants—are facilitated by the close spacing of the housing units. Freed from some of the physical chores of existence, many of the city dwellers have time for cultural development.

Denseness of population in urban areas entails certain disadvantages, too. Housing space per family is likely to be small, air impure, and sunlight insufficient. In many neighborhoods there is insufficient space for adequate outdoor exercise. In crowds, disease epidemics can spread fast, and insufficient exercise and poor light help to weaken resistance to disease. Traffic congestion has become a leading problem of many cities. Dense rural population (Illus. A, p. 13) does not have these urban problems.

From the social viewpoint, there is considerable question as to the desirability of city environment for rearing children. The individual adult, unless he is a leader, is likely to be submerged in the crowd and is in danger of losing some of the independence of thought and action characteristic of the countryman. In times of economic depression, city dwellers, most of whom are employees, are severely affected and have no natural products of the land to fall back upon for food if unemployed. Recreation is largely commercialized, and some individuals are likely to spend their leisure time in passive recreation rather than in quiet visits with family and friends for reading, thinking, and friendly conversation. Such treasured and inspiring moments are more characteristic of the country than of the city.

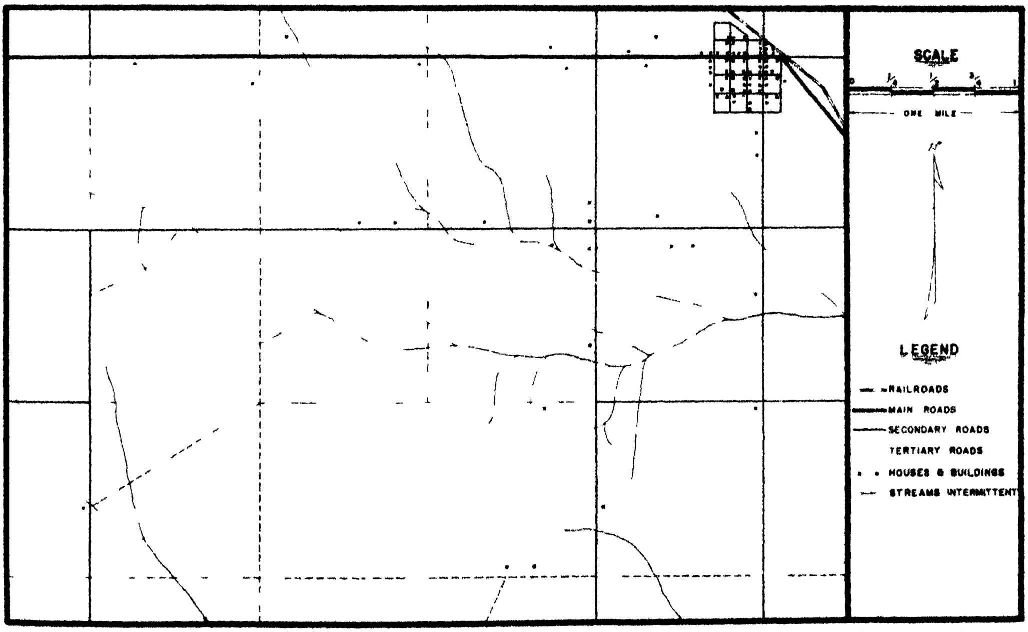
Advantages and disadvantages of sparse population. The availability of abundant sunshine, pure air, and space and freedom to exercise are some of the advantages of sparsely populated areas from the health viewpoint. The farm (of some types) commonly provides an abundance of food at reasonable costs, and more roomy living quarters, so that children are more likely to be welcome than in a city apartment. The feeling of closeness to nature is an indefinable satisfaction of living where sunrise, sunset, woods, and streams can be seen in all their beauty.

Certain phases and types of farming have been conducive to philosophical and religious thought. Some of the greatest books of the Bible were developed by the shep-



Adapted from topographic maps of Belgium

(A) Dense rural population near Thielt, Belgium



Adapted from soil survey of Box Butte County

(B) Sparse population on Nebraska High Plains herds of Palestine as they watched quietly over their flocks at night. In other Mediterranean lands, like Greece, the clear nights provided a fascinating canopy of sky for the shepherds to study, and from this area come many of the myths associated with heavenly bodies. The solitude of the country rather than the bustle of the city is conducive to this type of thought. (Illus. below.) In countries of winter snows the winter is sometimes a period of comparative leisure, during which people can develop their intellectual and social proclivities.

One of the major natural handicaps of sparsely populated areas is the expense, often prohibitive, of providing some of the utilities that make life more pleasant or efficient. With houses far apart, it is seldom feasible to lay sewer systems, gas lines, or, in some cases, even to provide for electricity or running water. (Illus. B, p. 13.) Again, because of the distances involved, there are likely to be no doctors or hospitals readily accessible, and thus undue reliance may be placed on nostrums and unqualified medical advice. In many rural areas the farm employees and tenants, as distinguished from the owners, find highly inadequate housing.

Because recreation involving groups is limited, emphasis is likely to be placed upon the weekly trip to church, occasional fairs, and other special opportunities for group activities. People who live isolated lives can hardly be expected to develop the art of eloquence: they are likely to be quiet and somewhat reticent in conversation, though quick to act when occasion demands.

Since sparse and dense populations both make their distinctive contributions to the life of society, and areas of moderately dense population present still other conditions, it is necessary at this point to examine more closely the actual distribution on the earth of populations of various densities.

Present distribution of population. Europe is the most densely settled continent, Australia the least, as the following list shows:

Approximate Number of People per Square Mile

World	12
Europe	140
Asia	67
North America	20
Africa	14
South America	14
Australia	2.5

While it is interesting to know about such broad differences, they mask the facts of actual distribution because each continent has different proportions of densely settled and sparsely settled land. Though North America as a whole has 20 people per

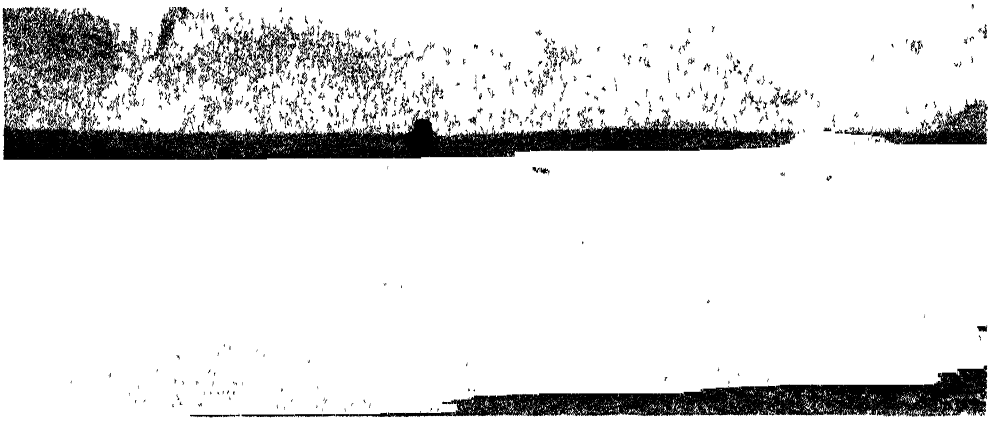


Photo by N A B

Sheep herder north of Hardin, Montana

square mile, the United States has 48 (in 1949), and within the United States Rhode Island has over 600, whereas Nevada has 1.2 per square mile. The map on page 16 shows actual world distribution of population regardless of international boundaries.

The densely settled lands. The map on page 16 shows that three parts of the world stand out above all others in density of settlement: southeastern Asia, central and northwestern Europe, and northeastern United States. Southeastern Asia has by far the largest population: nearly half the inhabitants of the world. The people are concentrated especially in the great river valleys and coastal plains of India and China and on the islands of Japan and Java. The density figures for China as a whole (about 140 per square mile) and India (215 per square mile) obscure the fact that densities exceed 1,000 per square mile in the best farmland areas in those countries. Japan has 530 per square mile and Java, with still less wasteland, has 940.

In northwestern and central Europe England leads the procession with 750 people per square mile and is followed by Belgium with 711 and the Netherlands with 661. Only slightly less crowded are Germany (432), Italy (372), Switzerland (267), and Denmark (227). Poland, Czechoslovakia, Austria, and Hungary belong to the 200–300 zone, too.

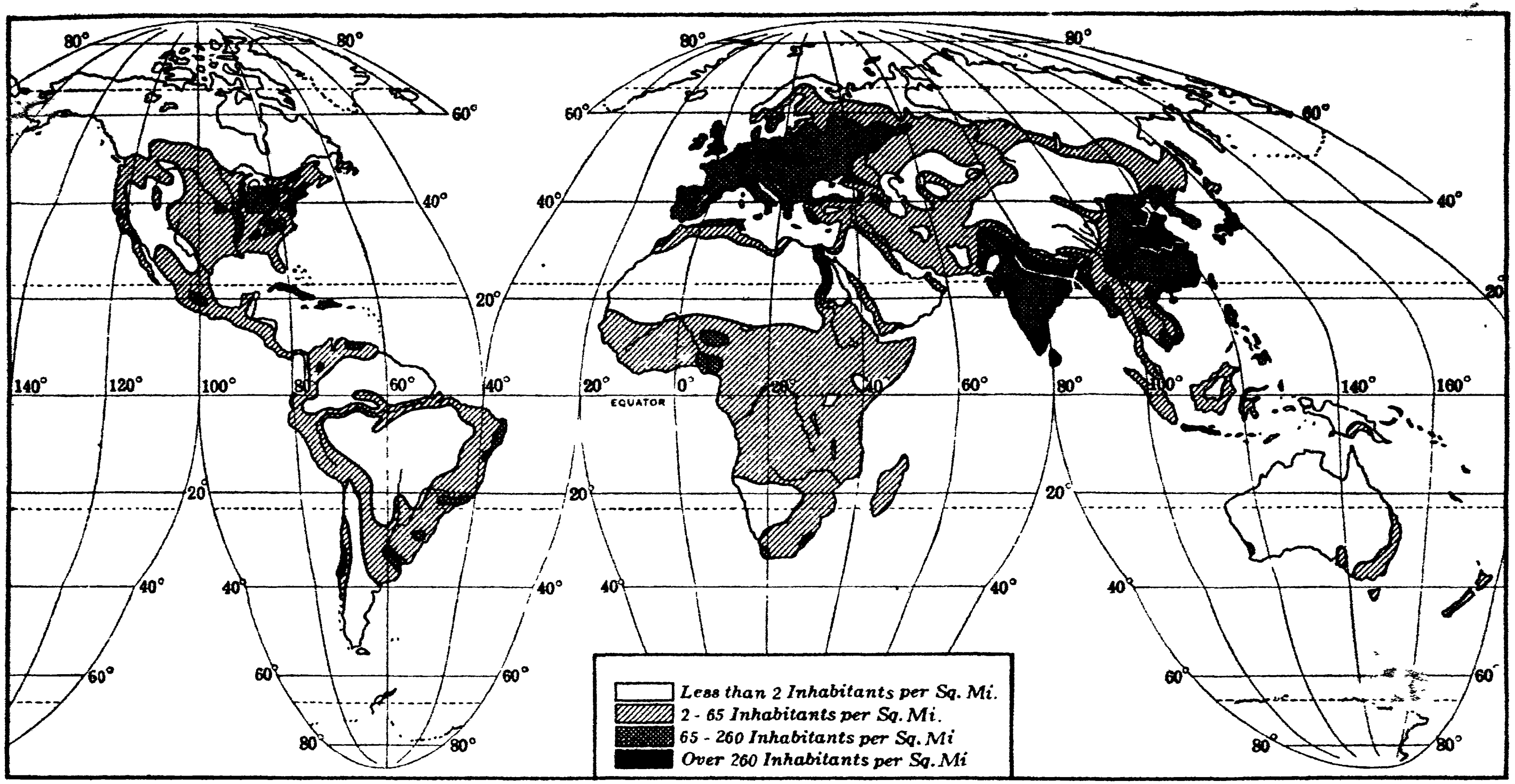
In the northeastern United States, the area between Baltimore and Boston compares with the dense populations of northwestern Europe: Rhode Island (614), New Jersey (590), and Massachusetts (561) all rise above 500 per square mile. Most of the industrialized district adjoining and between New York and Chicago attains similar densities, though the inclusion of sparsely settled areas within the state boundaries leaves the ratios for the entire states somewhat lower (Connecticut 395, New York 286, Pennsylvania 232, Maryland 202, Ohio 186, and Illinois 149).

In addition to the "big three" areas of dense population, there are many smaller areas of equally crowded conditions: islands such as Bermuda (1,759 per square mile), Barbados (1,266), and Puerto Rico (544); areas in the immediate vicinity of large cities; and intensive agricultural oases like the Nile valley. It would be a valuable exercise to note and explain the spots of dense population shown on the map.

Causes of dense population. What powerful magnets have attracted so many people to the areas of dense population, when only a short distance away are areas almost uninhabited? Although every area is unique as to the exact combination of factors operating within it, there must be some factors both of environment and of social institutions favorable for the development of a dense population.

Favorable *environmental* factors may consist of good land with climatic and water conditions suitable for crops; the availability of useful minerals; and a location favorable for trade or industry. The population of southeastern Asia depends primarily upon its excellent soil, well situated for supplemental irrigation during dry periods and enjoying a year-round warm climate (moist at least in summer) favorable for crop growth. Though valuable minerals exist, they have been developed only to a slight extent. and foreign trade. too, is insignificant in proportion to the population.

In western Europe, soil and climate are moderately favorable for crop production, though winter dormancy is a limiting factor. More important in explaining the great population density in Europe is, first, the existence and mining of coal, iron, and other minerals, and the use of the minerals for intensive manufacturing; and second, the excellent location of these countries facing the North Sea and Atlantic Ocean, with natural ports for carrying on trade with one another and with the rest of the world. For little countries such as the Netherlands, Belgium, and Switzerland the factor of location at crossroads or outlets of large countries with active trade is particularly important. The northeastern United States resembles northwestern Europe in depend-


EQUATOR
Less than 2 Inhabitants per Sq. Mi.
2 - 65 Inhabitants per Sq. Mi.
65 - 260 Inhabitants per Sq. Mi
Over 260 Inhabitants per Sq. Mi

After various sources   Goode's Interrupted Homolosine Projection, by permission of University of Chicago Press.

Density of population of the world.

ing for its great population more upon the exploitation of mineral resources and an excellent natural location for world trade than upon its farmland, though it too has some excellent local farming tracts.

While environmental factors may be said to set the limits of development in an area, *social* and *historical* factors are extremely important in deciding how the geography of population shall develop. The technology of a people is a major factor: the ability to practice large-scale utilization of machine power in manufacturing, for example, is just as important for Europe and the United States as the existence of the potential source of power in the form of coal. Japan, with much poorer soil resources than China, nevertheless developed a dense population after Commodore Perry opened the door that admitted Western techniques of manufacturing and trade. The sheer time factor, too, plays its part: people with technical backgrounds have been living longer in Europe than in the United States, especially in the interior and west of the United States, and the population has been producing goods and multiplying for a longer time in Europe.

In an agricultural area, dense population over a long period of time presupposes an adjusted, intensive form of land use, such as that developed in China and Java. Low living standards have contributed to the possibility of existence of so many people in the Orient. if every Chinese demanded the living standards of the average American, ruthless competition would fast decimate the economically weaker among them.

Modern technology in the field of health, by decreasing the death rate, has played a large part in population increases, not only in modern European and American countries but also in areas administered by these countries, such as Java and Puerto Rico. The attitude toward size of families is an overwhelming factor in population geography. The craving of the Chinese family for numerous sons, social and religious pressures for large families in other areas, and pressure and propaganda by political leaders (Hitler and Mussolini, for example) for bigger crops of potential soldiers so that they can conquer more land to take care of their bigger crops of boys and girls, all play their part in building up the population. The degree of effectiveness of such propaganda may be open to question, but that it can be a factor of some importance is generally conceded.

Another factor that has been particularly important in maintaining the dense populations of northwestern Europe has been the ability to obtain outside income, that is, to draw upon the resources or aid of other countries to feed and supply the home population. Such income is the so-called "invisible exports" bringing in revenue from merchant shipping, expenditures of tourists, income from investments in other countries, and gifts and loans from abroad. World War II reduced the income of northwestern Europe from all these sources. Before the war, for example, the British merchant fleet was twice as large as that of the United States. Now the ratio is reversed and the United States' merchant tonnage is twice that of Britain. While the United States' shipping increased 350 per cent, Japanese merchant shipping declined 80 per cent owing to the activity of American submarines.

It is perhaps not a mere coincidence that the three most densely settled countries of Europe are the heads of rich colonial empires, a further possible means of channeling outside production to the homeland. The most densely settled independent country in the Orient, too, was in the midst of developing a huge colonial empire when World War II began. Following the war, Japan lost her empire, the British gave up India, the Dutch hold upon Java weakened, and of the countries mentioned only Belgium appears to have retained intact its overseas empire, the Congo. Even in the United States the ability of the northeastern area to draw upon the production of the West and South through its capital investments has diminished, partly as a result of the wide dispersion of industry throughout the country during the war. To the dense populations, the reduction of their outside income may be a serious matter in terms of living standards.

The thinly settled lands. Study of the map of world population (page 16) shows that the most thinly settled areas, those with less than 2.5 people per square mile, cover about half the land of the world. Areas with less than 70 per square mile would include perhaps 75 per cent of the land. These lands are shunned largely because of the physical environment: social and historical factors have little bearing on the situation. If we compare the map of world population with the map of world climate, it is clear that three kinds of climate are associated with most of the blank areas: (1) the polar and subarctic climates of Siberia, northern Scandinavia, northern North America, and Antarctica, inhospitable because of their cold; (2) the desert and near-desert climates, including the Sahara and Kalahari deserts of Africa, the Arabian, Turkestan, and Mongolian deserts of Asia, the Great Australian Desert (Illus. above), the Great Basin and interior plateaus of the United States, and the dry lands of Atacama and Patagonia in South America, inhospitable through excessive dryness; and (3) the tropical rain-forest climates of the Amazon Valley, New Guinea, and northern Australia, inhospitable through the combination of excessive heat and humidity and the resulting character of the soil. Rugged mountains and cold high plateaus, notably Tibet, should be added to the list of sparsely settled areas. Where there is not enough heat or water to raise crops, or where there is an excess of both heat and water, only exceptional and local combinations of other factors will result in sizable settlements.

Courtesy Official Secretary for Australia in U. S. A., New York.

A sheep "station" or ranch in the sparsely settled grazing area east of the interior dry lands in Queensland, Australia.

Arctic and subarctic conditions are reflected in the population density figures for Iceland (4 persons per square mile), Canada (3), Alaska (1 person for 10 square miles), Greenland (1 person for 50 square miles), and Antarctica (0). Deserts are largely responsible for the densities of 2.5 people per square mile in Australia, 6 in Oman, 1.5 in Mongolia, 1.5 in Libya, 5 to 8 in the Somalilands, 1 in Southwest Africa, 0.3 in Rio de Oro, and 1.2 in Nevada. In the United States all five of the Western intermountain states, plus the northern plains and mountain states of Wyoming, Montana, and the Dakotas, have less than 10 people per square mile. The dry west is the principal area of sparse population in this country. Representative of the tropical areas are the Guianas, ranging from 1 to 4 people per square mile, French Equatorial Africa with nearly 4, and Dutch New Guinea with 2.1. Most of the African tropical land, including the Belgian Congo, has about 15 to 25 people per square mile.

For most Arctic areas, little can be done to increase the number of self supporting settlers, except through development of local mineral resources or transportation centers. Desert soils can support large numbers of people per square mile only where water is available from more humid areas, as in the Nile valley, small areas in Russian Turkestan, and our Imperial Valley, Reno, and Great Salt Lake areas. The United States is singularly blessed in having the well-watered Sierra Nevada and Rocky Mountains alongside its deserts, but the utilization of their water to support oasis populations in the deserts is commonly contingent upon control of water by means of man-made dams. Even if all available water were used, vast tracts of dry land still would be unirrigated. In tropical rain forests there is theoretically the possibility of developing productive farms with dense agricultural populations. Such development has actually occurred only in limited areas under exceptionally favorable natural conditions and expert management from outside, as in Java, the coastal plains of British Guiana and Surinam, and Nigeria.

Areas of intermediate population density. Between the small portions of the world with dense populations ranging above 200 per square mile and the vast realms with less than 25 per square mile, transition is abrupt in the Orient. From the teeming plains of the Ganges in northern India or the Yangtze in central China one climbs the adjacent mountains and finds himself at the edge of virtually uninhabited expanses. Only in the zone between India and China is there a sizable oriental area with moderate population densities, between 50 and 100 per square mile. Here Burma, Siam, and Indochina constitute the area where there is a surplus production of the staple oriental grain, over and above the needs of the local producers.

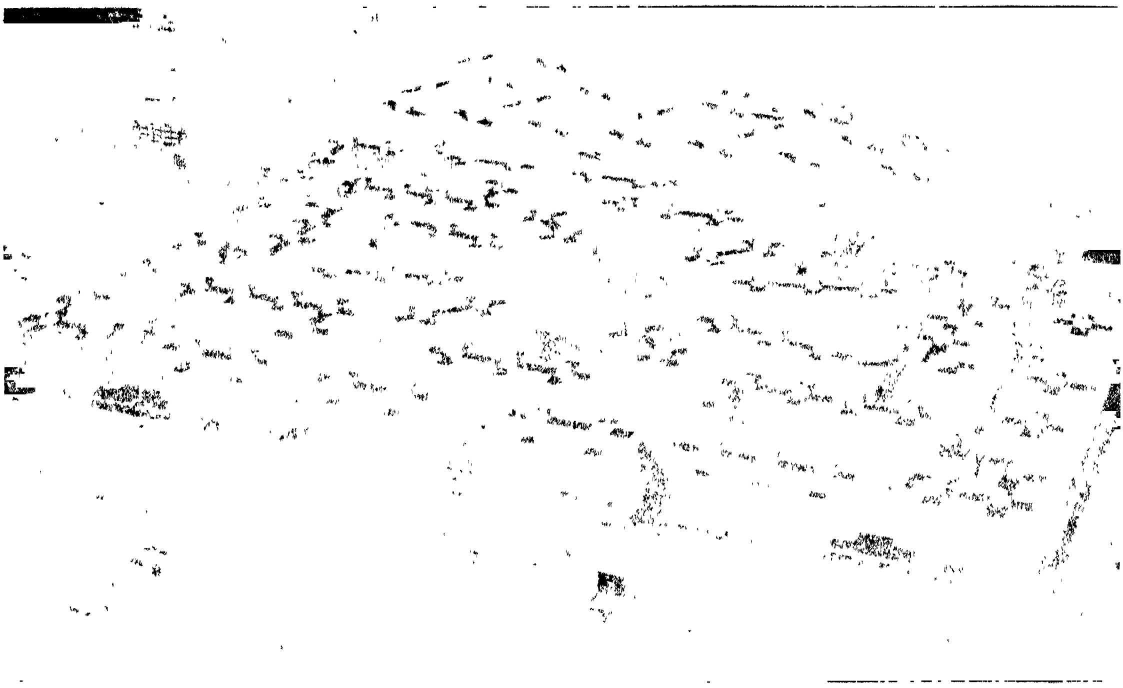
Around the European and United States population nuclei, on the other hand, there is a gradual tapering in density away from the center. The European "inner penumbra," countries with populations between 100 and 200 per square mile, includes, in a clockwise direction, Ireland, Scotland, southwestern U.S.S.R., Romania, Bulgaria, Yugoslavia, Greece, Spain, and France. Most of these countries are largely agricultural, raising enough food for themselves and sometimes having surpluses to send to their more closely populated industrial neighbors. The "outer penumbra," with densities between 50 and 100 per square mile, includes such diverse areas as the southern half of Sweden, Turkey, northern Algeria, and Morocco. Here agriculture is approaching the physical margin of productivity so that most food is consumed at home, except for the wheat and wine of Algeria.

Around the New York-Chicago broken nucleus, the population penumbra falling within the category of 50 to 100 people per square mile, includes the corn belt and the adjoining cotton belt states, and southern Ontario in Canada: areas with large agricultural surpluses to supply the nuclear district. Only as we get into the Texas-Kansas-Minnesota belt do densities drop below the 50 level.

In South America, Africa, and Australia, moderate population densities are found only in small, widely scattered areas, mostly along the outer rims of the continents. Examples include the Santos, Pampas, Valparaiso, Callao, and Caracas centers of South America; South Africa, Nigeria, the Gold Coast, and Liberia in Africa; the Perth, Sydney, and Melbourne areas of Australia;

and New Zealand. In the East Indies, the Philippines, Sumatra, and Timor densities are moderate; but most of the other islands, except Java, are thinly settled areas of tropical rain forest and mountains.

Is a moderately dense population preferable to a dense or sparse population? Is life more pleasant there, and frictions less? Such questions cannot be answered flatly. There seem to be balanced cultures in areas of almost every shade of population density, and spots of misery in areas of as many shades, too.



Courtesy Thomas Airviews, Bayside, New

Stuyvesant Town and Peter Cooper Village, recent apartment house projects replacing a blighted area in New York City

Economic-geographic effects of population densities. The personal effects of dense population have already been suggested. From the impersonal economic viewpoint, the existence of a dense population is important as furnishing an abundant supply of labor and a large consuming power. Production and consumption are of course two aspects of the same people. The availability of abundant man- (and woman-) power favors the development of manufacturing industries in an area. As each new industry is established or each old one enlarged, purchasing power of the area becomes still greater and there is a still larger market for manufactures, agricultural products, and services. The higher the productivity and wages of labor—as a result of adequate resources, skill, technology, management, and capital—the larger the market will be. This compounding process helps explain the population increases of new industrial areas.

One of the great handicaps in developing industries or commercial agriculture in sparsely settled areas is the lack of adequate manpower with which to start the industry and the lack of a sizable local market to consume the products. As a result, valuable products that can stand the expense of shipment to distant markets are sometimes the first commercial products to come from such areas: as furs before lumber.

The works of man are profoundly affected by population densities. In a crowded city, the chief problem is how to squeeze homes, factories, stores, streets, traffic, and transportation terminals into a limited space (Illus. p. 20). But, in rural areas the problem is how to provide the minimum essentials of utilities, roads, and services in view of the expenses resulting from wide spacing of homes and the low revenues of local political units because of limited tax revenues (Illus. above and B, p. 13).

Overpopulation. How many people per square mile must an area have to be overpopulated? To this question there can be no one answer: when people applying their best skills to the resources of an area are unable to attain an adequate standard of living, that area might reasonably be called overpopulated. If a semiarid land can support only two herdsmen per square mile, three persons per square mile would be too many. But if an industrial district with 2,000 people per square mile pays good wages but still cannot get enough workers, that district is underpopulated. When it comes to applying this formula to a specific area, however, the answer may not be easy to find. Perhaps the three herdsmen (with help) can drill a deep well, install a modern pump, and irrigate enough land to support 100 people per square mile.

Nutritionists have estimated that the product of about two and one-half acres is needed to provide an adequate standard of living for a human being. There are many variables and unknowns in this rough formula, but it gives us some sort of yardstick for estimating adequacy of land. There are in the world not more than four billion acres of arable land for the slightly more than two billion people: not quite two acres per capita. This would suggest that the world as a whole is overpopulated. It is certainly true that a large percentage of the billions do not have an "adequate" standard of living. Differences between countries in the per capita amounts of arable land are of course profound. If we compare three great countries having about 450 million acres of arable land apiece, we find that the United States has more than three acres of arable land per capita, the Soviet Union close to two and one-half, and India and Pakistan a little more than one. Even without other factors, these differences help to explain the semistarvation that prevails in India, the adequacy of food supply in Russia and America, and the existence of an exportable surplus in the United States. In China, with not quite one and one-half

Photo by N. A B

Rancher's cabin northwest of Rawlings, Wyoming.

acres of arable land per capita, it is estimated that 100 million people have died of starvation in the last one hundred years. Some authorities believe that the population of China reached its present level about one hundred years ago. In industrial northwestern Europe, there is still less arable land. The United Kingdom, Belgium, and the Netherlands have just over one-fourth acre of arable land per capita, Germany two-thirds acre, and Italy and Greece three-fourths acre. Yet, widespread starvation is not the rule in northwestern Europe because it has been able to draw surplus food from all the continents of the earth by one means or another to feed the people who did not emigrate. In particular, power machine technology has enabled Europe to sell manufactures in exchange for needed food and raw materials.

Remedies for overpopulation. What can be done to solve the problem of misery and starvation resulting from inability of a given people to obtain sufficient income? It seems clear that either resource utilization must be improved to support the people who already exist, or the population must be decreased. The problem is complex, but certain partial solutions have been used and are being used constantly.

More adequate resource utilization. As the centuries have rolled by, man has learned more and more about how to obtain larger production from his resources. The raising of livestock and the practice of agriculture resulted in greater and more dependable output of food per acre. Improvement of farm machinery; use of fertilizers and discovery of ways of obtaining or manufacturing fertilizers; use of green manures and compost; improvement of crop rotations and putting the right crops on the right land; development of breeds of plants and animals that produce more per acre; development of better control of insects: such methods have increased production in the past and have possibilities for further development and, especially, for further extension. It has been estimated that the application of proper conservation methods alone would increase crop production in the United States 20 per cent; the development and use of hybrid corn has increased yields in our corn belt perhaps 20 per cent between 1936, when it was just getting established, and 1948, when nearly 100 per cent of corn planted in the corn belt was hybrid. Such increase in yields has made it possible for America to send additional food to the deficiency areas of Europe.

Vast increases in the world's food still can be made if the crowded farmers of Europe and Asia will systematically use the best modern techniques and plant varieties adapted to their conditions. The Food and Agriculture Organization of the United Nations has been carrying on with considerable success an educational and aid program to spread throughout the world high-yield crops and animals, methods of disease control, sound crop rotation, and erosion control.

For an individual country, the development of industries through which manpower can be applied to raw materials, and thereby turned into manufactures, provides one means of getting an income from which purchases of food can be made abroad. Every increase in our knowledge of more efficient ways of utilizing power resources and other resources makes the world more able to support mankind. This truth was the basis of Europe's ability to draw food and raw materials from the rest of the world to support its dense population, and for the ability of the northeastern United States to obtain sufficient food from the rest of the country. It is also the basis for the dense population of Japan. Such an application of industrial knowledge, however, requires the use of capital, or social savings, and is therefore difficult of application in countries such as China or Greece where the people live too close to the margin of subsistence to have accumulated savings. The reason for capital loans from the United States to Europe are obvious even in normal times. The tremendous destruction of accumulated capital equipment from bombings during World War II is of course a powerful added reason for great capital needs in Europe since the war. It is estimated that the patiently accumulated capital of one hundred years was wiped out by the Fascist and Nazi invasion and occupation of Greece, and in Yugoslavia the destruction was about equally great.

Industrialization results temporarily in a burst of growth in the population of a country. The European countries have passed that stage. Would industrialization of China and India mean still further large increases in their population?

Solutions involving the people themselves. 1. Emigration. When people feel too crowded to obtain an adequate income, many of them in the past have simply left their homelands and struck out for the frontiers of the earth—areas where there was plenty of farmland per capita or plenty of demand for industrial labor. The New World was populated in this way from all parts of Europe. The amount of immigration from individual countries has fluctuated in accordance with changing pressures: at the time of our last census the United States had 34½ million white people who had been born abroad or who had one or both parents born abroad. The most numerous groups according to origin were from Germany (5.2 million), Italy (4.6), United Kingdom (3.2), Poland (2.9), Canada (2.9), Russia (2.6), Eire (2.4), Sweden (1.3), and so on. Other frontier lands have been similarly settled from densely populated lands: Spaniards and Italians in Argentina, Chinese in Manchuria, Russians in Siberia, British and French in Canada, and British in Australia. Such emigration may temporarily relieve population pressures at home, but this method of relief is becoming less and less available; as the receiving countries have grown in population, they have shut or closed to a small crack the door to prospective immigrants.

Some shifts of population are still to be expected, but most areas of scant population, with the possible exception of the tropics, are not adaptable to supporting many immigrants. The influx of Jews into Palestine and its new state of Israel has shown that there are parts of the semiarid lands of the world in which the application of modern production techniques, with the aid of abundant capital and skilled population, can enormously increase the capacity of the land to support people. California, very much like Palestine in environment, experienced a similar upsurge of production with the aid of people and capital from the more developed parts of the United States.

Just before and during World War II great shifts of population occurred in Russia, chiefly from the southern grain belt to new industrial centers across the Urals, stimulated by the release of farm population through the introduction of large-scale machinery and, during the war, by the Nazi invasion of the grainland. Within the United States sharp movements of population have been under way ever since the Atlantic coastal area was settled from Europe. In seven years after the census of 1940, including the period of World War II and the immediate postwar years, the three Pacific states showed huge gains of population, Oregon increasing 50 per cent and California and Washington only slightly less. The states with the biggest percentage decline in population during this period were not the densely settled eastern states, all of which showed substantial increases, more than 15 per cent in Connecticut. The big declines came in the northern Plains states: North Dakota, South Dakota, and Montana all dropped 10 to 15 per cent.

2. Reduced living standards. Another so-called solution of overpopulation, which is really not a solution, is to submit to a gradual decline of living standards. That is actually what has happened in the Orient, to the point where further appreciable decline has become impossible. Starvation, epidemics, and misery are the ultimate results of this "solution."

3. Lower birth rate. A decrease in the number of people from causes other than emigration is an important possibility. The Malthusian theory that disease, starvation, and wartime slaughter normally may be expected to keep population numbers in check is not consistent either with man-

kind's humanitarian ideals or with our modern knowledge of disease prevention, high per-capita production techniques, and means of communications which, rightly used, could enable all peoples to understand one another's problems. Once we recognize the impossibility of supporting decently an unlimited number of people, the question arises whether it is really the patriotic thing to encourage high birth rates that must result in still further crowding of an overtaxed world.

Northwestern Europe, alone among the great populated areas of the earth, has reached the stage where births and deaths are approximately in balance. In Germany and Italy before the war Hitler and Mussolini made frantic efforts to bribe and encourage the people to have more children so that their countries would be able to wage successful war. The United States before the war was rapidly approaching the balanced birth-death ratio of northwestern Europe, but the ratio of births rose sharply during the war. The high birth rate of thinly settled Russia (with about 23 people per square mile in 1949) was a striking phenomenon before World War II. However, the huge losses of manpower during the war, equal to the combined losses of all other combatant nations except China, gave the Russian rate of increase a sharp setback, although even before the war the birth rate had begun to decline somewhat. In the Orient, where the population pressure is most severe of all, reduction of rate of births would be a merciful development. Convincing the people of the desirability of limiting the number of births encounters the difficult obstacles of tradition and prejudice on the part both of the givers and the receivers of the education.

Significantly, there is a running argument between the biologists, who say we must reduce the birth rate or submit to brutal reduction by pestilence, disease, and war, and the technicians in the field of agriculture and resource utilization, who stress the vast increases in production possible as modern research progresses and as its findings become more and more universally applied. To the geographer concerned with a balanced economic development of the earth's surface, it appears that resources and population must be considered simultaneously. A sound geographic goal would be a population in every area balanced at a level where it could be adequately supported on the basis of resources available locally and through trade. The attainment of such a goal is a challenge to the best knowledge and patience of mankind.

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Chapter Three

THE EARTH AS THE HABITAT OF MAN

In the preceding chapter we were introduced to the distribution of population on the earth and some of the causes and effects of uneven distribution. Our concern was primarily with people and with the problems of life and of land use that have resulted from living crowded together or widely scattered.

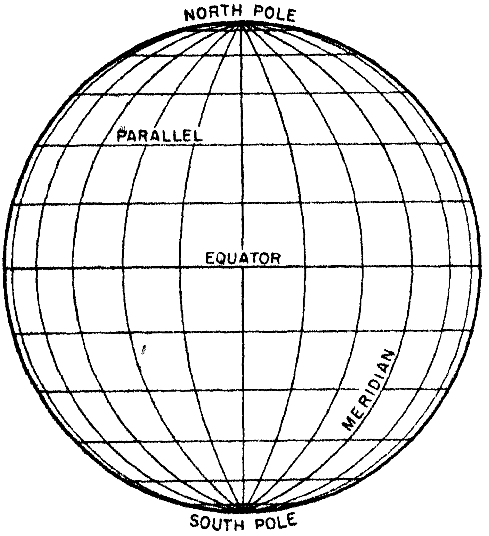
In this chapter we shall deal with some of the major aspects of the planet earth on which we find ourselves. The form of the earth, together with its motions and the great divisions of air, water, and land, are fundamental not only to our existence but to our ways of making a living. The earth, in its broad sense, includes the air we breathe, the water we drink, and the rocks and minerals which give rise to our soils, our plains, and our mountains. It includes the resources we use for building homes and factories, manufacturing pots and pans, refrigerators, furniture, automobiles, airplanes, and the great ocean liners. The earth is a vast organism upon which man lives and does his work. In the present and succeeding chapters we shall try to become better acquainted with it as the home of man.

The nature of the earth and its relationship to the sun are of utmost importance if we wish to understand the material basis for human life upon the globe. The sun is the principal source of energy for life on the earth. The continual changes between day and night, summer and winter, the great differences in climate in various parts of the world, the existence of the mineral fuels, the character of soil and organic life, all these and many other factors that directly affect mankind are the results of the place and the movements of the earth in the solar system.

Limited observation led early man to believe that he inhabited a flat earth, either round or oblong. Long before the Christian Era, however, keen observers decided that the earth was a sphere. Pythagoras, a Greek philosopher who lived about 500 B.C., seems to have been the first exponent of this conception, on purely philosophical grounds. Aristotle, who lived about 350 B.C., first drew attention to various phenomena which indicate a spherical form for the earth. Columbus did not originate the theory of a spherical earth: his great contribution was his willingness and ability to apply the theory to daring action.

Today we know that the earth is almost spherical, with a diameter of nearly 8,000 miles and a circumference of a little less than 25,000 miles (Illus. p. 26). As the earth bulges slightly toward the equator, we usually refer to it as a spheroid. As a celestial body, the earth is but a speck of dust in the endless universe. To man who travels about on the speck, however, it seems huge. The volume of the earth is about 260 billion cubic miles; its surface area is about 197,000,000 square miles. We could spend a lifetime wandering about and see but a fraction of what the world has to offer.

Earth spheres. Our planet, the earth, includes an envelope of air and great expanses of water as well as solid land. We can think of the earth as consisting of three roughly concentric spheres: the *lithosphere* (rock sphere), the *hydrosphere* (water sphere), and the *atmosphere* (gas sphere). Plant and animal life occur in all three of these spheres. There is no life in the deep interior of the earth nor in the higher part of the atmosphere, and but little, if any, in the ocean deeps. Biological activity, including human activity, flourishes most near the zone of contact between the atmosphere and the other two spheres. This zone of life, where plants and animals find optimum conditions for food and the other essentials of existence, is the principal concern of economic geography.



Poles, meridians, parallels, and equator. Perspective view of earth globe.

THE ATMOSPHERE. The atmosphere envelops the lithosphere and the hydrosphere, but it is just as integral a part of the planet as is rock or water. Except for the differential movements of winds, the atmosphere rotates along with the lithosphere. The atmosphere is a substance of economic importance. It is the substance that supports airplanes in flight. Air in motion, or wind, may be utilized as a source of power in propelling ships or in turning windmills. Air in excessive motion, as in hurricanes or tornadoes, may be one of the most destructive forces of Nature.

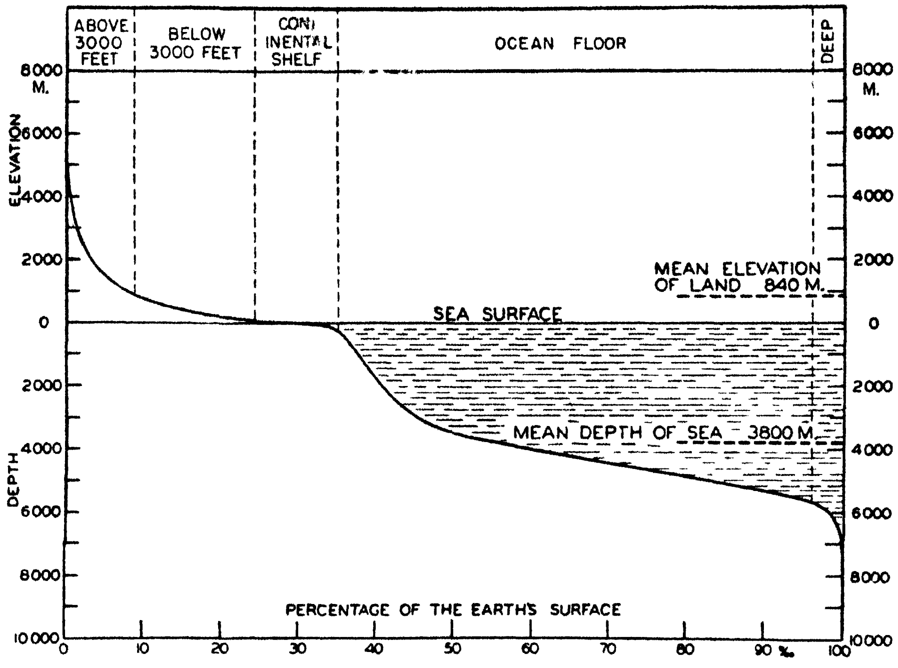
Though the atmosphere extends more than 200 miles above sea level, its density decreases rapidly upward. The barometer proves that one-half of the air, by weight, lies between sea level and 3.2 miles above. The lower part of the atmosphere, where most of the weather phenomena take place, is known as the *troposphere* (sphere of change). The relatively quiet air of higher elevations is called the *stratosphere* (layered sphere). The mass, or weight, of the atmosphere is estimated to be about 1/1,200,000 of the mass of the solid earth and 1/270 of that of the hydrosphere. Man lives and moves near the bottom of this atmospheric ocean, the presence of which is so unobtrusive that he forgets its existence except when he feels the wind. Nevertheless, it is an essential ingredient of life for all warm-blooded animals, including man. The geographic aspects of the atmosphere in their relationships to climatology and to human activities are discussed in Chapters Five to Sixteen.

THE HYDROSPHERE. The hydrosphere, or water sphere, exists for the most part in the depressions of the rock sphere, but because of its penetrative qualities some water is found in the pore spaces of rock, and much exists in the troposphere in the form of water vapor. The great bulk of the water on the earth forms the oceans, which cover about 72 per cent of the surface. The average depth of the ocean is more than two miles. The greatest known depth, 35,400 feet, occurs east of the Philippine Islands in the Pacific. In the Atlantic Ocean the maximum depth so far discovered is in the

Milwaukee Deep north of Puerto Rico, where a sounding of 30,246 feet has been made.

The waters in the air and in the ground are vital to plant and animal life. Soil moisture not only furnishes the solutions of minerals necessary for plant food, but it also furnishes the liquids for circulation among and through plant tissues.

The earth's water goes through an interesting cycle. By evaporation from the oceans and other water bodies, and by transpiration from plants and animals, water enters the air as water vapor, a gas; winds transport part of this water vapor over the land; from the air, moisture is precipitated upon both sea and land; on the latter it forms lakes, streams, soil water, and ground water; from the land it flows back to the oceans, or returns directly to the air through evaporation and transpiration. This interrelation of hydrosphere, atmosphere, and lithosphere is vital to the continued existence of plant and animal life.



Continent in relation to ocean. Epicontinental sea, overlying shelf, is ordinarily less than 600 feet deep. Most of ocean floor has water depth of more than 10,000 feet

The most favorable conditions for marine life are found in the shallow waters bordering the continents. (See Physical Map of the World, frontis.) Here the contact zone of water and ocean floor is within reach of the heat and light transmitted by the atmosphere, and the plankton and fish populations attain maximum abundance. Prominent examples of such favorable conditions are the Grand Banks off the coast of Newfoundland and the shallow waters of the North Sea, each the center of a great fishing industry.

Geographic aspects of the hydrosphere are discussed in some further detail in Chapter Seventeen, and in the climatic chapters preceding it.

The lithosphere. The lithosphere, or rock sphere, is the solid part of the earth. Its surface is characterized by broad corrugations; the extensive higher portions are known as continental platforms and the extensive lower lying portions as ocean basins. Every continent has marginal areas that are covered by relatively shallow ocean water; these shallow water areas are known as *epicontinental seas*. The epicontinental seas thus are distinct from the ocean basins, and their floors or *continental shelves* really are parts of the continents (Illus. p. 27).

What is the land? People of different locations and pursuits would answer this question in many different ways, though there might be some agreement on the bookish definition. To the apartment dweller of New York City, land is a material so scarce that buildings have to grow vertically instead of horizontally. To the Eskimo, land is a seasonally exposed material useful as a summer source of berries and caribou meat to supplement the diet of fish and blubber. The farmer of Norway thinks of the land as hilly, stony, and hard to conquer, whereas the farmer of Iowa thinks of it in terms of abundant corn and hogs.

Pearl Buck's novel, *The Good Earth*, portrays an attitude toward the land that is almost poetic in its intensity. In this novel the soil and the elements are pictured as the fickle masters over the life and death of teeming millions of passive, helpless Chinese. Vivid pictures of Wang Lung and O Lan ministering to the earth will come to mind. Every growing plant receives the tending care of their anxious hands If the land produces generously, a few ounces of meat may be procured for a holiday; if it yields niggardly, a young daughter must perhaps be sold into slavery and infamy. Wang Lung loves to walk in newly turned soil, to feel the earth with his bare feet. He loves to rest and even to sleep in a sun-warmed furrow so that he can feel and smell the earth. He hopes to be buried in the better earth.

Economists often use the term "land" to include all natural resources, as distinguished from labor and capital, the other two factors of production. For our purposes, land may be defined according to the narrower and more widely used concept, as *the portion of the surface of the lithosphere not covered by water*. Under this definition small bodies of water that do not dominate the general landscape are considered part of the land. Large rivers and lakes, and shallow waters around the seashore, are not included. Land exists because the uneven surface of the lithosphere causes some parts to project above the oceans. The total area of the oceans is about 143,000,000 square miles, whereas the total area of the land is only about 54,000,000 square miles.

The foundation materials of the land. The land and the ocean basins are underlain by rock. The character of the rock often affects the land forms and soils, and thus rocks have a general importance quite aside from their direct economic importance in mining. The characteristics of rocks, in turn, depend to a considerable extent upon the types and arrangements of the minerals of which the rocks are composed. To understand more fully the relation of rocks to their economic uses, a brief introduction to the most common minerals will be found helpful.

Minerals. A mineral may be defined as a *natural inorganic earth substance with a definite, essential chemical composition* Minerals may contain also various nonessential constituents. For example, quartz, the most common single mineral of the land, is essentially a chemical compound of silicon and oxygen. In its pure state it is colorless, but most quartz has some color due to the presence of impurities, such as iron oxide, manganese compounds, carbon, rare earths, and other foreign matter.

Although there are more than one thousand different minerals, the bulk of the common rocks of the land are composed chiefly of a very few minerals. Among these common rock-forming minerals are quartz, feldspar, mica, hornblende, and calcite. Minerals such as sulphur, common salt (halite), nitrates, potash, and phosphates are of direct economic value but are unimportant in rock forming. Their uses and economic importance are discussed in Chapter Eighteen, and we shall limit ourselves here to a brief treatment of the importance of a few minerals especially significant in relationship to soils.

Quartz, a hard, light, relatively insoluble mineral, greatly improves friability in the soil. It makes the texture relatively open, and therefore facilitates the ready movement of ground water and air. The physical condition of the soil is thus made much more favorable for penetration of plant roots and for cultivation.

Feldspars are of great importance in the formation of soils, being one of the principal sources for clays and for the mineral salts which are essential as plant foods, as the principal products of their decomposition are clay, sand, and soluble salts.

Hornblende, the most common hard black mineral, has no direct economic use, but it has great geographic significance as it is present in many rocks and decomposes into sand, clay, and soluble salts.

Calcite is important for soils because it is the chief constituent of chalks and limestones. The presence of lime in a soil may greatly contribute to its fertility and suitability for tillage purposes.

Rock. In its broadest sense, rock refers to any of the solid part of the earth. It does not imply any particular degree of coherence or hardness. Even sand, dust, silt, and coal are rock in this broad sense.

On the other hand, the term *stone* implies coherence and is used as a term for some kinds of rocks, such as limestone and sandstone. Thus, ordinary sand, a phase of rock, is called *sandstone* if the sand grains are found cemented together so as to form coherent rock.

In a restricted sense, rock is a *natural earth substance with a specific, characteristic mineral composition.* All rock is composed of minerals. The simplest types of rock are made up of one predominant mineral, while the most complex rocks contain a large number of minerals. A complex rock, such as granite, contains certain characteristic minerals, but the proportions of the different minerals vary widely and cannot be represented by exact, uniform ratios or formulae such as are used in indicating the chemical composition of minerals

Bedrock. The solid zone of the lithosphere is commonly referred to as *bedrock.* In most places the bedrock is covered by a mass of loose material varying from a few inches to many feet in thickness. As this debris overlies the bedrock, it is known as *mantle rock.* If formed through weathering from the bedrock underneath, it is called *residual* mantle rock; among the various types of deposited mantle rock, alluvium is perhaps the most important. Mantle rock is not itself soil, but it is the parent material out of which soil may be developed through the action of various weathering processes and by changes brought about by organisms. The mantle rock, although often erroneously referred to as *soil,* is merely the raw material for true soil.

There are comparatively few common types of bedrock, and their principal characteristics can be summarized easily. As bedrock is the fundamental material of which the land is made, and as it has certain direct economic uses, it deserves at least brief consideration.

Part of the effect of bedrock upon the configuration of the land results from differences in susceptibility to weathering and erosion. When inclined strata of soft and hard rock are exposed in adjacent position, the soft rock commonly wears away the more rapidly, forming valleys and lowlands, while the hard rock remains standing out as ridges. (Illus. p. 30.)

In excavating for construction purposes, similarly, work can proceed more easily in soft than in hard rock The depth of bedrock below the surface of the mantle rock also greatly affects construction. Where bedrock is close to the surface of the ground, it impedes the excavation of cellars, canals, and similar works. At the same time, the bedrock provides a substantial foundation for heavy buildings, bridge piers, and dams; walls of cellars, ditches, and subways need little artificial reinforcement once they have been carved into the rock. The hard bedrock of Manhattan Island provides a firm foundation for the world-famous skyscrapers of New York and gives permanence and security to its efficient subways, though the cost of construction was high.

Where the bedrock lies deep below the surface, costs of excavation in the mantle rock are low, but costly foundations, floors, and retaining walls may have to be constructed. Ditches, drainage canals, and basements for ordinary residences and business blocks can be constructed at comparatively low cost.

The industrial uses of rock are dealt with in Chapters Eighteen and Nineteen. Some of the principal types of rock are as follows:

Classes of bedrock. Bedrock is customarily classified, according to its origin, into three main groups: *igneous*, *sedimentary*, and *metamorphic* rock. *Igneous* or primary rocks are formed by the cooling and solidifying of hot molten material (magma) from within the earth. In most igneous rocks, such as granite and basalt, the different minerals, in whole or in part, have separated into individual crystals which interlock with one another in the rock. In some instances the magma cooled so fast that the minerals did not have time to crystallize, and the result is a glassy rock, such as obsidian.

When existing rocks have been broken down into small particles by weathering processes, these particles may be transported by an agency such as running water and deposited in layers. Such redeposited rock is called *sedimentary* rock. Clays and shales, sands and sandstones, gravels, and limestones are examples, though the latter are generally of organic origin.

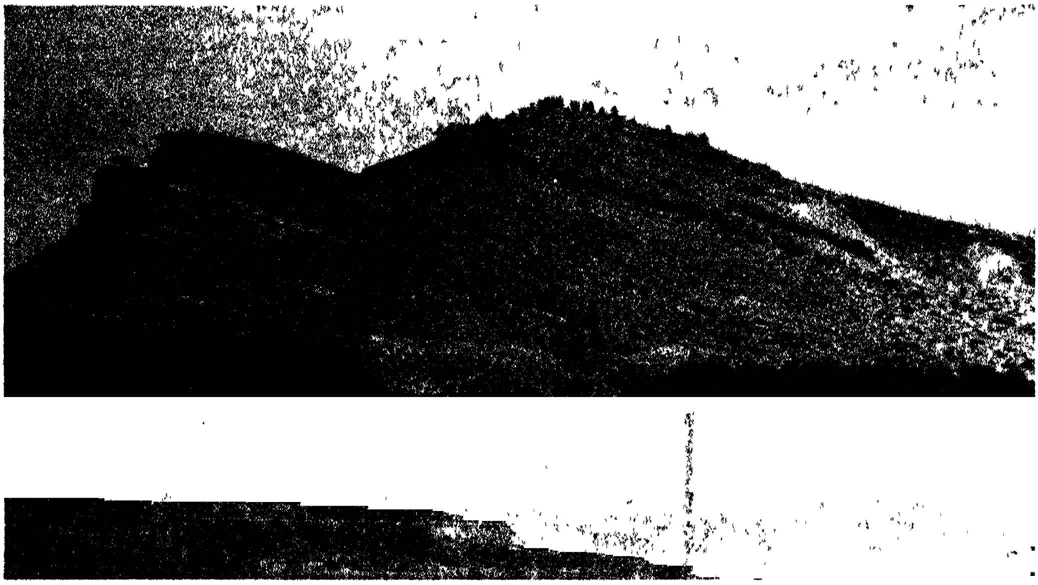


Photo by N A B

Differential erosion of weak and strong strata in tilted position in mountain foothills of the front range of the Rockies, west of Loveland, Colorado

Another type of rock is formed when existing igneous or sedimentary rocks are subjected to intense heat or pressure and are thereby changed in character, or metamorphosed. These are the *metamorphic* rocks. Thus quartzite is metamorphosed sandstone, gneiss may be metamorphosed granite, marble is metamorphosed limestone, and slate is metamorphosed shale.

Major land forms and internal forces. The configuration of the earth's surface is the result of two sets of forces: (1) internal forces within the earth that have raised some parts of the earth's crust and depressed others, or that have folded or broken (faulted) the crust, and (2) external forces that tend to wear down the higher portions of the land and build up the lower portions. The great continental masses and ocean basins are results of the internal forces. The internal forces also are largely responsible for the development of the major surface features of the land: the plains, plateaus, and mountains.

The internal forces are commonly grouped under the headings of *vulcanism* and *diastrophism*. Vulcanism, named after the Roman underground god of fire, involves the movement of molten magma and its outpouring in the form of lava on the earth's surface, sometimes accompanied by explosive releases of gases. Viscous types of lava, such as andesite, tend to pile up and form steep, lofty volcanic mountains, like Mount Hood and Mount Vesuvius, composed of alternate layers of solidified lava and fragments from explosions (Illus. below). More liquid types of lava, such as basalt, often spread horizontally, and form plains or, if there are a great many successive flows, may build up plateaus like the plateau of Iceland or the Columbia Plateau of our own northwest.

The term diastrophism, from a Greek word meaning distortion or deformation, designates the internal forces that move existing bedrock. These forces may produce a vast, gentle uplift or depression of the earth's crust, producing plains if uplift is moderate, plateaus if it is greater, and ocean basins if depression is sufficient.

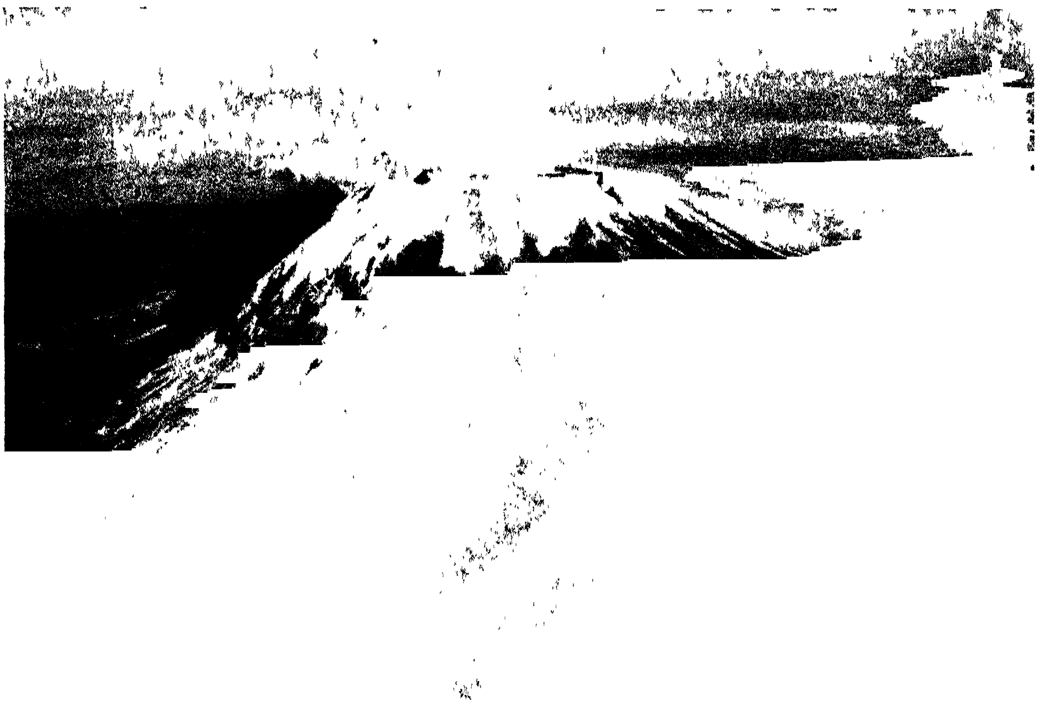


Photo by Mary Light in R U Light Focus on Africa, American Geographical Society

Kibo, 19,590 feet in elevation the summit of Mt Kilimanjaro and the highest peak in Africa Although less than 4 from the equator, the crater of this volcanic mountain is filled with an ice cap that sends glaciers down the sides as low as 12,500 feet Above about 11,000 feet is a zone of Alpine grasses, and below that the forest

More intense expressions of diastrophism take the form of folding or fracturing of the bedrock. *Folding* is due to lateral pressure. The Appalachians, Alps, and Himalayas are among the numerous folded mountain ranges of the world. Vertical movement along a fracture or *fault* in the bedrock also may cause mountains or troughlike valleys. Thus, the Sierra Nevada was formed by the tilting of a mass of bedrock along a fault at its eastern base, and Owens Valley developed as a trough at the eastern base of the Sierras. The upper Rhine Valley, the Scottish Lowlands, and the Jordan Valley are well-known examples of troughs where sections of the earth's crust have dropped between parallel faults.

Plains, plateaus, and mountains. Though these terms are useful and widely used, it is difficult to draw sharp lines between each of these land forms. They may be defined broadly on the basis of altitude, relief, and steepness of slope. Geographically speaking, the altitude of anything is its height above sea level. *Relief,* as applied to an area, is the average difference in elevation between the highest and lowest parts of that area. An undulating plateau has low relief, even though it may have high altitude. Steepness of slope sometimes is even more important than elevation or relief in affecting the cultivation of the land or the building of transport routes. Elevation can be represented much more easily on a small-scale map than relief or slope, and therefore it is the basis for the world map in the front of this book.

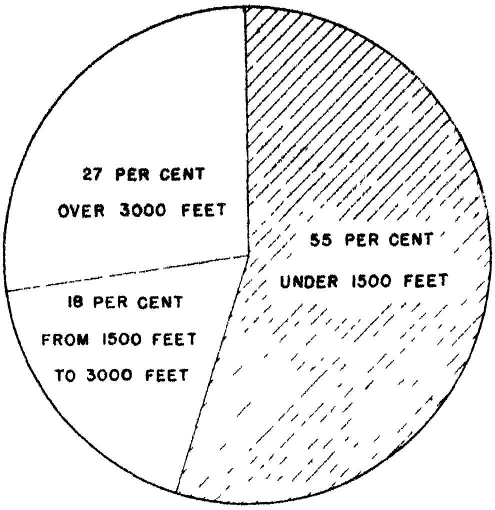
Plains are lands of low relief and usually low elevation and gentle slope (see Physical Map of the World in Chapter Seventeen). Some areas now called plains may actually consist of low hills that have been eroded from land that had less relief in the geologic past. On the physical map the large green areas represent the principal plains of the world.

Plateaus are areas of low or moderate relief, lying at relatively high elevations. They are set off from adjacent plains or mountains by fairly steep descents or ascents. Among the world's most extensive plateaus is the high plateau (over 10,000 feet elevation) of Bolivia, the Altiplano; the moderately high plateaus (about 5,000 feet) of the African lake district and Colorado Plateau of the United States (Illus. p. 414); and the low plateaus (2,000 to 4,000 feet) of central India and Arabia. Difference in altitude alone is not the only distinction between plains and plateaus: portions of the Great Plains of the United States are higher than the low plateaus just mentioned. On the other hand, certain areas, like the Appalachian Plateaus of the United States, are called plateaus even though they consist in large part of steep-sided hills and mountains. They were plateaus in the geologic past, but only small patches and strips of the original plateau surface remain, the rest having been cut away by erosion. Geographically, such areas are mountain or hill lands rather than plateaus.

Mountains are lands of relatively great relief and steep slopes, with small summit areas. The highest known point of land is Mount Everest, in the Himalayas, with an altitude of about 29,141 feet. The lowest land is the shore of the Dead Sea, in Jordan Valley, 1,292 feet below sea level. Thus the extreme relief of the entire earth is 6 miles: a mere surface scratch compared with the 4,000-mile radius of our globe.

The plains of the world. Fortunately for man's economic development, more than half the world's land consists of plains. About 55 per cent of the land area lies at elevations of less than 1,500 feet, compared with 27 per cent above 3,000 feet (Illus. p. 33). In most respects, plains have the most favorable conditions for plant and animal life and human occupance. Those areas contain the least stony and the most productive soils, while lack of great relief or steep slopes insures relative safety from erosion of their soil material. Road and railroad transportation encounter no major obstacles aside from water bodies; many rivers are navigable.

It is no accident that by far the greatest percentage of the world's population lives in plains areas, as in northwestern Europe, southern Russia, central United States, northern India, and parts of China. In the fertile alluvial lowlands of the Ganges, the Brahmaputra, the Hwang Ho, and the Yangtze Kiang concentration of population is particularly great. There are, of course, some plains that are sparsely settled. The plains of northern Canada and northern Asia are sparsely populated because of long winters, and those of Turkestan, because of aridity. Such plains may never be able to support a dense population. In fact, according to a recent estimate, only about 30 per cent of the land surface is sufficiently level, warm, and moist to be considered capable of producing ordinary crops. The plains are the seats of greatest industrial progress as well as of greatest agricultural productivity. On them have been built most of the cities of the world and on them are found the principal centers of cultural achievement.



Percentage of land surface at stated elevations

Mountains and plateaus: distribution. Although mountains occupy only a small percentage of the earth's surface, their conspicuous and impressive appearance attracts attention and they also have distinctive significance from the viewpoint of economic geography. A glance at the Physical Map of the World reveals that the greatest mountain ranges of the earth lie in two principal zones: one around the Pacific Ocean, the other running east-west through Asia and Europe. The first zone carries a series of active volcanoes along the crest of the Andes, through Central America and Mexico, California, Alaska, Kamchatka, Japan, and the East Indies, and is therefore sometimes called the *Rim of Fire of the Pacific*. Folding and faulting have built up mountain walls in this zone, which includes the Andes, Sierras, and Rockies of western America. Earthquakes are common in many sections. Lines of islands, the peaks of mountains rising from the ocean, are links in this system of mountain ranges such as the Aleutians which run from Alaska to Kamchatka, the Kurils from Kamchatka to Japan, and the Ryukyus from Japan to Formosa.

The second system of mountain ranges is commonly referred to as the Alpine system after one of its best-known members, the Alps of Europe. It extends from Morocco and Spain to New Guinea. To it belong such well-known mountains as the Himalayas, Hindu Kush, Elburz, Dinaric Alps, Carpathians, Apennines, and Atlas. Near and within it lie plateaus and plains, such as the plateaus of Persia, Anatolia, and Spain, and the plains of Hungary and Walachia. Uplands not related to the two main zones, such as the Appalachians, the Brazilian Highlands, and the Scandinavian Highlands, show lower altitudes or less relief.

Economic aspects of mountains. From the viewpoint of economic geography, there is an important distinction between mountains which are covered with vegetation to their summits and those which rise above the tree and grass line. The vegetated type provides more opportunity for forestry and grazing, and, in addition, it is usually less rugged and more rounded of slope, thus forming less of a barrier to movement than the other type. To this type belong

Courtesy U S Forest Service.

(A.) **Forest-covered mountains in Washington.**

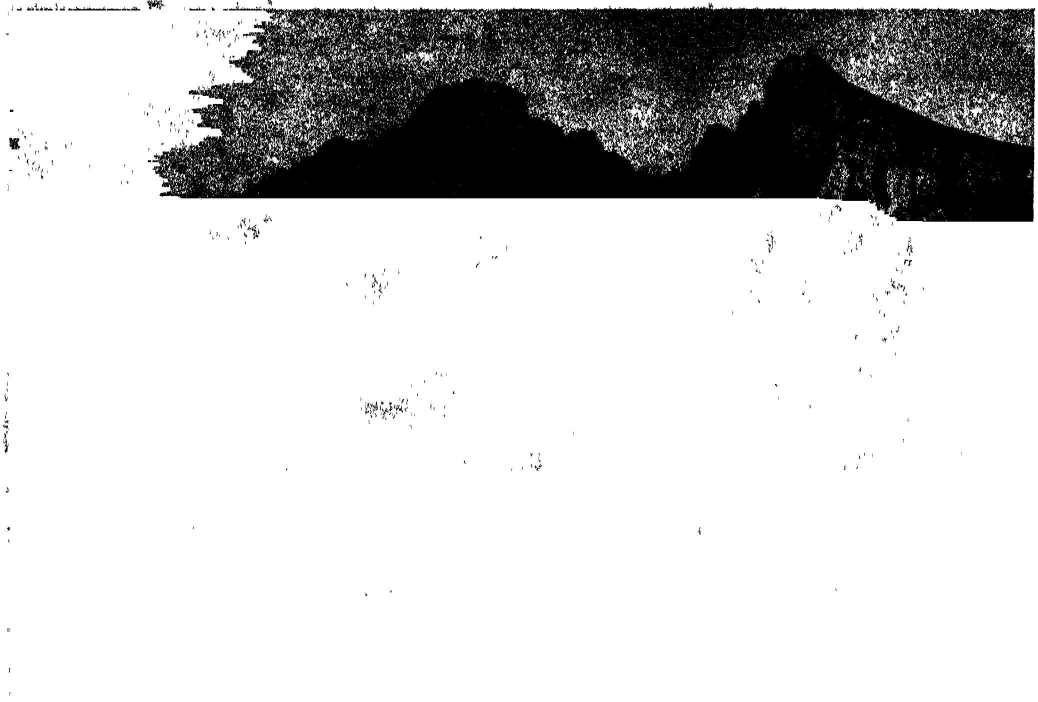


Photo by G Muller Courtesy Official Information Bureau of Switzerland in N Y.

(B) Conditions above the tree line

such ranges as the Appalachian, Pacific Coast Ranges (Illus. A, p. 34), the Jura, and the Black Forest, all with wooded, rounded slopes and sheltered coves.

Mountains with barren peaks rising above the tree and pasture line are called *Alpine* because of their resemblance to the Alps of Europe (Illus. B, p. 34). The higher parts of such mountains often contain permanent ice fields from which glaciers move down toward the valleys. The unprotected slopes are attacked by frost and insolation weathering, and sharp peaks and ridges are the result. While glaciated zones occur in very high mountains of all latitudes (Illus. p. 31), and the tree line and snow line get lower and lower toward the poles, until mountains near the Arctic Ocean have no trees at all and glaciers reach all the way down to the sea as in Greenland and Antarctica.

Even in areas of rugged mountains there are commonly ways in which a sparse population can make a living. Agriculture ordinarily can be carried on only on the floors of the lower valleys. ✓Animal industries are more important in the mountains than tillage agriculture In many mountains of Alpine type there is a zone above the tree line and below the snow line where grasses and other forage plants flourish. This vegetation furnishes summer pasture for cattle and sheep, and there develops a seasonal migration between these summer pastures and the winter headquarters in the valleys below. Such transhumance is common in the western United States as well as in the mountains of Europe and Asia.

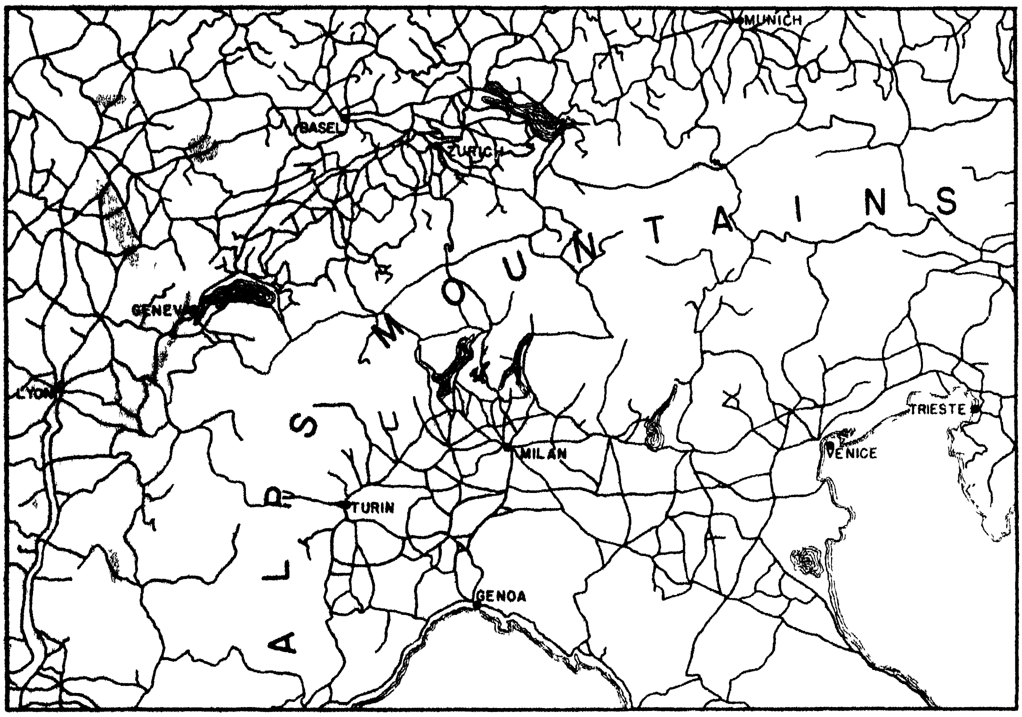
✓Mining is another common occupation in mountains. Mountain areas often consist partly of igneous and metamorphic rocks which may be rich in ores of copper, gold, silver, lead, zinc, and other metals. In the United States mining is the principal pursuit in many districts of the Rocky Mountains.

Possibly the principal economic role of mountains is of a negative character. Mountains form not only climatic barriers, but also barriers to transportation, and thus to commercial intercourse. For centuries China was practically isolated from the western world by the mountain masses of interior Asia. In America the Appalachians were long a barrier which hindered the westward expansion of the early colonists. In Europe the east-west mountain barrier favored the independent development of distinct cultures in the south and north.

Transportation across mountain regions necessarily follows the relatively low passages, known as *passes*, which usually are comparatively few in number (Illus. p. 36). Construction of roads or railroads across steep passes is often difficult, and the higher passes are blocked by heavy snow during the winter season. With the advance of technical knowledge, man has learned to build better roads and to pierce mountain ranges by means of tunnels, some of which are many miles long. Construction of such tunnels, however, is an arduous and costly undertaking. Mountain ranges will always remain economic obstacles to commercial intercourse. Even when crossed by modern roads and railroads, the upkeep of the routes and the extra power and fuel needed to overcome the steep grades remain a continuing expense.

Although mountains are not of great direct economic value, we should not forget that, as a result of their height, they receive large amounts of precipitation in the form either of snow or of rain, and that this moisture is often indispensable to the plains below them. The cotton raising of Russian Turkestan depends upon the snows of the Tien Shan and Hindu Kush Mountains for irrigation water, just as the fruit and rice production of the Great Valley of California depends upon Sierra Nevada snows. The height of the mountains also results in a coolness that makes them a refreshing summer retreat for people from the hot lowlands. In addition, the steeply descending rivers are available for generating hydroelectric power.

Plateaus vary greatly in altitude. In warm, tropical regions plateaus of moderate elevation offer the best sites for human activities. The high plateaus of Kenya, Tanganyika, South Africa, and Ethiopia have a healthful climate which facilitates agricultural development. The plateaus of southern Brazil are the most densely populated part of the entire country. In Colombia the plateau of Bogota is a densely settled area, with diversified agriculture, industrial activity, and cultural progress. Some extensive plateaus, like the Mongolian plateau of Asia, are dry as a result of the surrounding mountain barriers, and support a sparse grazing industry and limited irrigation.



Railroads of Alps and neighboring territories. Barrier effect of high mountains clearly shown

Land forms and the external forces. With the limited vision imposed by his short tenure of life, man is inclined to look upon the mountains of the earth as symbols of eternity. Among some primitive peoples the mountain tops are thought to be the sites from which the spirits of the departed forever watch over their descendants. In Japan, Fujiyama symbolizes all that is old and hallowed by tradition and all that lasts while generations come and go. The cosmic order, however, recognizes no such thing as permanence, and even the most majestic mountain systems are subject to that fundamental law of Nature which decrees everlasting change.

Wherever bedrock is exposed to the air, it is attacked by forces which lead to its disruption. Other forces transport the rock fragments downhill. Some mountain peaks, apparently consisting of solid rock, are so thoroughly decayed at their summits that a famous Alpinist once exclaimed. "Give me a crowbar and I will lower them!" (Illus. p. 37.) Mountains—and whole mountain systems—wear away, although at a rate so slow that only by studying the results can man grasp the significance of the forces and processes involved. In Europe, the low mountains and hills of Belgium, Brittany, and central France once probably reached Alpine heights. In the United States, the Appalachian mountain system has suffered immense erosion in the course of its long existence.

From the point of view of economic geography it is fortunate that mountains are not the permanent features of the landscape that they are commonly believed to be. Most of the mantle rock of the earth is the result of the slow decay of mountain masses, and the mantle rock gives rise to *soil*, the essential base for plant growth and agriculture.

Rock decay or weathering. The first step in wearing down mountains is rock decay, or *weathering*, induced by exposure to the elements and by the attacks of organisms. Weathering may involve only the breaking up of rock masses into smaller particles, or it may involve complete changes in the composition of the constituent minerals of the rock. The mechanical type of weathering is termed *disintegration;* the chemical type, *decomposition.*

Photo by N A B.

Weathering in mountains. Cloud descending on ridge near summit of Long's Peak. Temperature changes and freezing have caused crumbling of rock.

DISINTEGRATION. Like most substances, rock expands when heated and contracts when chilled. Just below the surface, temperature changes are slight. During the day, a rock surface may become heated intensely by solar radiation. This unequal heating leads to unequal expansion and results either in the scaling off of the outer surface or in fragmentation of the rock, especially when the heating during the daytime is followed by rapid cooling at night or by a sudden downpour of cold rain water. The unequal rates of expansion of the constituent minerals also causes fragmentation of such rocks as granite and gneiss. This alternating expansion and contraction is an important factor in desert regions and in high mountain areas where a protective vegetation cover is absent and where there are sharp contrasts between day and night temperatures.

Moisture is often present in the voids and cracks of rocks. Upon freezing it expands about one-eleventh of its volume. In gaining this additional volume it exerts tremendous pressure. Voids and cracks are enlarged, and the cracks penetrate deeper and deeper into the rock, paving the way for complete disintegration. This type of weathering prevails where moisture is abundant, where temperature changes above and below freezing point are frequent, and where there is little or no vegetation cover to protect the rock. Such conditions exist above the tree line in (Illus. B, p. 34, p. 37) high altitudes and in high latitudes. Much frost weathering occurs even in middle latitudes during the winter season.

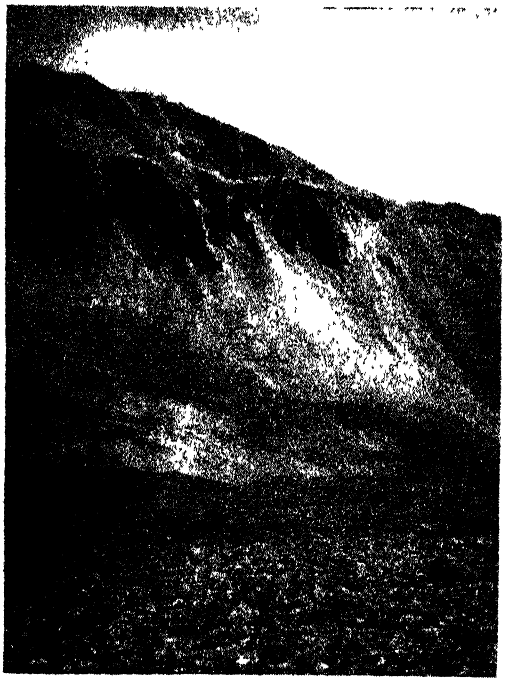
Decomposition. Water is the chief agent in crumbling rock by chemical processes. Pure water is chemically inactive, but water usually contains other matter and often occurs in ionized form. As the raindrops descend from the clouds, they gather carbon dioxide and oxygen; as they percolate through the soil, humic acids and other chemicals may be incorporated. Water so fortified can effect the crumbling and eventual wasting away of any rock.

Chemical weathering practically ceases at temperatures below freezing. This type of weathering therefore is unimportant in high mountain or polar regions. Since relatively high temperatures accelerate it, chemical weathering is most active in the warm and moist tropics, where rock sometimes weathers to depths of over a hundred feet. In regions such as the Congo or the Amazon basins, outcrops of solid rock are rare and are usually found only in stream beds. Because this is generally true even for areas of considerable relief, exploration for minerals is difficult in tropical rainy regions. In desert areas, chemical weathering plays only a minor role because of the lack of moisture.

Erosion and deposition. As soon as rock has been broken into smaller pieces by weathering, the force of gravity starts moving the weathered material downhill. The movement may occur either directly or through the medium of an agent of transportation such as running water, wind, waves, or ice. The processes of reduction of the land, especially the transportation aspect, are known collectively as *erosion*, from a Latin word meaning "to gnaw out" ("rodent" comes from the same root). The products of erosion eventually come to rest as deposits at lower levels.

The direct work of gravity is apparent in the sandy debris that covers the ground around the base of granite or sandstone rock outcrops. If cliffs are high, large fragments break off and pile up in steeply sloping accumulations known as *talus* at the base of the cliff (Illus. below).

Less spectacular but really much more important than mountain rock falls, is the downhill mass movement of mantle rock through the processes of landslides, slumps, or slow *creep*. This direct work of gravity, together with surface washing of particles, produces rounded slopes and transports to streams the material that makes up the greater part of their sedimentary load.



Courtesy U S Geological Survey, Washington, D C
Photo by I Howe

Talus slope on south side of Sheep Mountain, Colorado. Note badly weathered bedrock above the talus

Streams and other agents of transportation can carry the rock debris much farther than gravity alone. Besides transporting detritus great distances, the transporting agents also do some rock-carving of their own, with the aid of their corrasive load, wearing down their beds and cutting away their banks (Illus below)

The results of erosion may be either harmful or beneficial to man's economic interests In high mountain regions, which are usually sparsely populated, erosion does relatively little direct damage to human interests, in lower, hilly areas much good soil may be carried away by water, to the detriment of agriculture In southeastern United States, for example, accelerated erosion, so-called *sheet erosion*, resulting from unwise land use has become a serious problem

On the whole, however normal erosion is more useful than harmful to man because what rivers, glaciers, or wind transport they must deposit somewhere All the valley bottoms and most of the plains areas of the world have resulted from the deposition of rock waste removed from higher slopes For example, much of the upper bedrock and mantle rock of the Great Plains of North America and of the lowlands of northwestern Europe was derived either directly or indirectly by erosion from adjacent mountain areas It should of course be understood that these are processes that involve geologic ages, not time as usually measured by man in decades or centuries

Erosion and deposition by water. When moisture falls upon the ground gravity immediately causes it to seek lower levels Surface run-off and ground water result both giving rise to streams Many small streams, intermittent as well as permanent unite to form rivers which may drain large areas of land Most of the water of these streams ultimately reaches the sea In dry climates some drainage basins have interior drainage that is they have no outlet to the sea

Streams are the most important agents of erosion and deposition over much of the earth's surface The erosive capacity of streams depends upon their size and their velocity Those that have steep gradients are swift and can carry great loads of boulders gravel sand and finer particles

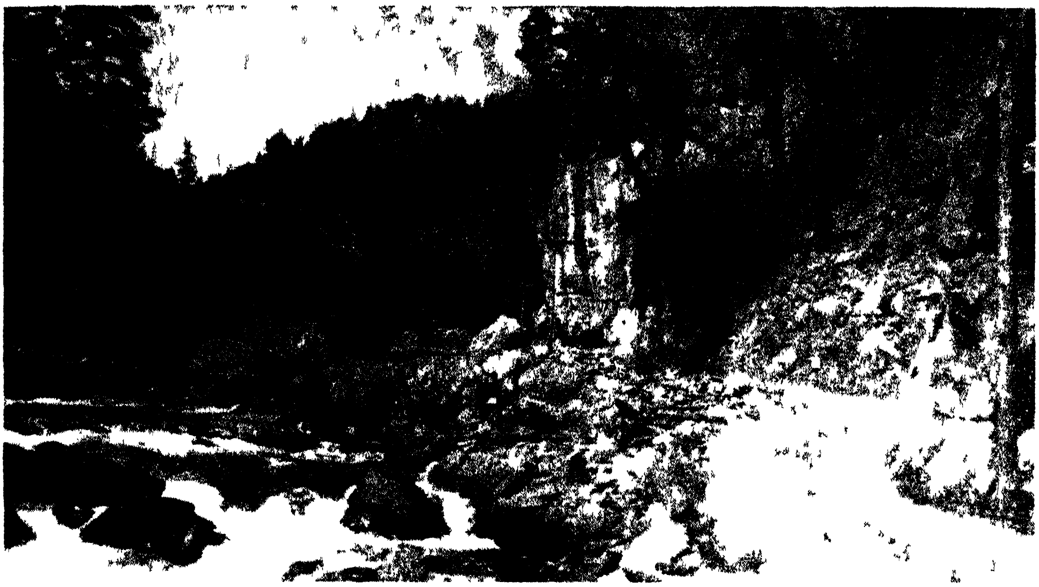
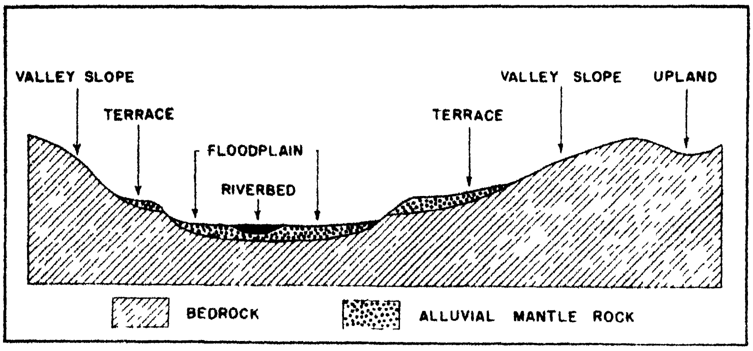


Photo by N A B

Boulders in stream bed of Big Thompson Creek across front range Colorado These boulders are moved when the water is high but remain lodged during low water stages When moved they scrape the stream bed and are reduced in size by the corrasive processes

This load corrades the stream bed vigorously if the stream is swift. The streams thus deepen their valleys and extend them headward farther back into the uplands. At the same time the network of minor streams becomes more dense: as a plant constantly grows new roots, so a river grows new tributaries. Thus all the higher land finally is dissected by river valleys, and the hills and mountains in between are slowly worn away. Downstream, where the gradient is gentler, the velocity of the stream decreases, and part of the load is dropped. The deposits tend to be sorted according to size of fragments. The largest stones, sometimes weighing several tons, are deposited in the stream bed in the upper part of the stream in or near the mountains (Illus. p. 39). Gravel and sand are deposited in or near the stream channel farther downstream. The finest particles, silt or clay, may be deposited some distance from the channel when the river floods, or they may be carried out to sea. Any rock debris deposited by running water is called *alluvium,* a special type of mantle rock.

Where alluvium is spread out upon the land by successive floods of the river, the resulting land feature is known as a *floodplain.* Floodplains usually are highest close to the river, where part of the load is dropped when the river velocity is first checked by friction when it overflows its banks. Back of the *natural levees,* thus formed along both sides of the river, are poorly drained basins where the finer materials, silt and clay, are deposited. Floodplains, with their deep alluvial soils, are some of the most densely settled agricultural areas in the world, like the valleys of the Nile, Ganges, and Yangtze rivers. If for some reason a stream that has been building a floodplain begins again to cut downward, the old floodplain may become a *terrace* (Illus. below). Because of their safety from floods and their good drainage, valley terraces are important not only as farmland but also as sites for towns and lines of transportation.



Floodplain and terraces

Alluvium deposited at a river mouth in a lake or sea forms a *delta.* The delta may gradually project far beyond the general coastline. In the course of successive changes of channel, the river builds in the delta a series of radiating branches called *distributaries,* with natural levees along the channels and marshy areas in between. Such land may be extremely fertile when reclaimed, as witness the rich, densely populated deltas of the Rhine River in the Netherlands, the Red River in Indo-china, and the Si Kiang in China.

The differences in the economic problems in different parts of a river system are well illustrated by the Missouri-Mississippi system. The Missouri rises in the northern Rockies and flows across the western Great Plains at an elevation of nearly one mile. Here steep gradients result in high velocities, and active downcutting of the stream channel results. The farmers of this area are interested in holding back the swift waters with dams and using them for irrigation. Below the mouth of the Missouri, the Mississippi River has a very gentle gradient and is aggrading rather than degrading. Here the people are most concerned with preventing floods and with maintaining a navigable channel. Near the delta the river is in places 10 to 15 feet above the level of the floodplain. It is confined to its bed by natural levees supplemented by man-made levees. As the river tends to build up its bed by deposition, the protective dikes must be built higher and higher, or the stream must be confined to a narrower channel by jetties so that the increased velocity will sluice the channel clear.

In arid areas, where streams dwindle away before reaching the sea, the entire load of detritus is deposited on the land. Steep *alluvial cones* and gentler *alluvial fans* are built at the mouths of mountain canyons, where stream velocity is checked as the streams emerge from the mountains. Alluvial fans and other natural barriers sometimes create basinlike areas, in which water collects after rainstorms or during a series of wet years, only to dry up during long dry spells, leaving glaring white flat expanses of accumulated salts. Such intermittent bodies of water are known as *playa lakes.*

A special set of land features sometimes develops in humid areas where the underlying rock is limestone or some other easily soluble material. Here the principal erosive action is due to the solution of the rock by water containing carbonic acid. As the water percolates through cracks in the rock, it dissolves vertical tubes into which the surrounding surface material erodes, forming funnel-shaped depressions in the land known as *sinks.* Some sinks develop into lakes without surface outlets. Surface streams are scarce or even lacking in such areas: surface water drains through the porous rock, through widened joints or sink holes, and flows away underground. As it flows underground, the water, by means of solution, creates winding caverns, resulting in some of the world's most spectacular natural wonders, such as Mammoth Cave in Kentucky and Carlsbad Caverns in New Mexico. The exposed surface rock in such areas may be dissolved along joints into a series of rough corrugations. Areas where rock solution dominates the landscape are known as *karst,* from an area in Yugoslavia where they were first described in systematic detail.

Still other types of land features resulting from water action are those caused by *waves.* Here again both erosion and deposition are important. The waves, especially along the seacoast during storms, may pound against the land with great violence. The coast is thus cut back, leaving steep cliffs. The debris eroded from the land is carried to sea by the undertow, and drifts along the coast with the currents and waves. The platform cut by the waves is thereby extended out from the coast by a built platform, and if the land later is raised or the sea recedes, a *marine terrace* is left exposed. The detritus carried along the coast by waves and currents may be redeposited as sandy *spits* projecting across the entrances of bays, or may form *barrier beaches* backed by lagoons along the mainland side, as is true of much of our Atlantic coast.

Erosion and deposition by wind. Whereas water erosion is most active in humid regions, wind erosion is more effective in arid and semiarid lands. In deserts and near-deserts vegetation is sparse, active weathering provides much loose material, and the particles are too dry to adhere to one another. Coarse sand and fine gravel are swept along the surface by strong winds, while the finer particles—such as fine sand, silt, and clay—are carried suspended in the air. As a result of the wind action the desert surface tends to become rocky, sandy, or silty.

Rocky deserts, known as *hammada* in the northern Sahara, develop when the finer particles have been blown away by the winds leaving bare bedrock and boulders on much of the surface. Sand grains can

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be moved by the wind, but are not usually carried very far at one time. They tend to be deposited on the leeward sides of deserts, or on rising slopes, where they form sandy deserts known as *ergs* in the Sahara. Ergs are generally less extensive than hammadas in the world's deserts.

In any area of abundant unprotected sand, along beaches as well as in deserts, the wind creates hills of sand known as *dunes.* Dunes slowly move across the land as the wind carries the sand particles up the gentle windward slope and drops them on the steep leeward slope of the dune. The largest areas of sand dunes are found in the great desert regions of the world: the Sahara, and the deserts of Arabia, Mongolia, and Russian and Chinese Turkestan. One of the large dune areas in the United States is near the Colorado River in California. There are extensive dune areas, now covered in varying degrees by bunch grasses, in parts of the Great Plains region of the United States, notably the Sandhills Region of Nebraska (Illus. right). As these dunes have reached virtual stability, they are called *fixed dunes.* Along seacoasts where beaches are sandy and the winds are mostly onshore, sand dunes sometimes develop and move inland. In northwestern Europe the westerly winds are thus responsible for the dune areas along the coasts from southwestern France to Denmark. Along the southern California coast the westerlies have provided similar dune fields convenient for Hollywood Saharan scenes. Low dunes occur along the Atlantic seaboard from Cape Cod southward.

Because of its movement, porosity, and relative sterility dune sand is inimical to vegetation. Attempts to anchor dune sands have met with varying degrees of success. In a relatively humid climate, as in western Europe and parts of the United States, some kinds of grasses and even trees can be grown, but watchfulness is necessary if plantings are to survive.

Material finer than sand may be carried by the wind, as dust storms, over considerable distances and upon deposition may give rise to extensive deposits of *loess.* Loess includes material which ranges in fineness from clay through silt to very fine sand and does not show regular stratification; in some places it has been reworked by water, in which case it resembles alluvial mantle rock. The most striking characteristic of loess is its porous but coherent structure, which enables it to stand vertically in cliffs, with little tendency toward sliding and slumping.

Loess deposits occur in three types of regions: (1) on the margin of desert areas, (2) in the near areas that have been subjected to continental glaciation, and (3) adjacent to the valleys of some major streams. The occurrence of loess under such widely different conditions suggests that it may have been blown (1) out of desert areas, (2) out of formerly glaciated areas before vegetation had re-established itself, and (3) out of wide floodplains. The most extensive loess regions are found in northern China, southern Russia and Siberia, and the central part of the Missouri-Mississippi drainage basin. Loess deposits have given rise to some of the world's most fertile soils. Their principal handicap from an agricultural point of view is that they occur mostly in semiarid or subhumid regions of undependable precipitation.

Photo by N. A. B

Grass-covered dunes and sandy road in the Nebraska sandhills

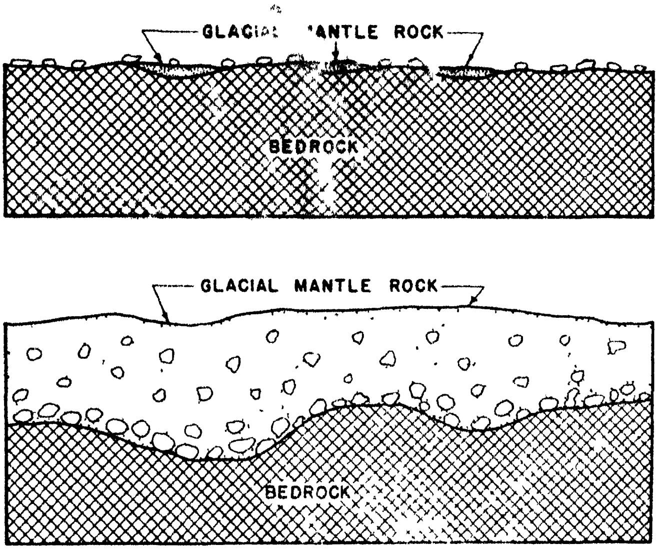
Glacial erosion and deposition. Erosion and deposition by ice profoundly modified much of the surface of the earth during the Ice Age, and still continues to do so in the polar regions and in the high mountain areas of the middle latitudes.

In high areas and polar regions, snow may accumulate from year to year, forming snow fields. Gradually the snow is compacted into ice, and as the ice mass becomes thicker and heavier, some of it begins to flow outward from its source in long tongues called *glaciers.*

In mountain areas the glaciers follow the mountain canyons and valleys. The weight of the glaciers, and the stones and grit embedded in their lowest layers, render them very potent in scouring and gouging the surface over which they pass. The glacial valleys become U-shaped through this cutting and sapping action, and striking bowl-shaped amphitheaters called *cirques* develop at the heads of the glaciers.

Extensive glaciation of large land masses has occurred at various times in the history of the earth. The last of these periods is commonly referred to as the Ice Age or the Glacial Period. During the glacial period, huge ice sheets, probably several thousand feet thick, formed in the northern parts of Europe and North America, and spread southward until one-half of each continent was covered. In North America the ice spread from three centers, the Cordilleran in the northern Rockies, the Keewatin west of Hudson Bay, and the Laurentian east of Hudson Bay. The evidence shows that probably four successive ice advances occurred, each extending varying distances into what is now the United States, and separated by long, practically ice-free periods. The earlier sheets advanced somewhat farther south than did the later ones

The forward movement of these enormous masses of ice resulted in a thorough scouring of the surface, especially near their centers of origin. Mantle rock and prominent bedrock masses were ground up and carried away (Illus. above). Basins were excavated in the bedrock. As a result of this glacial erosion, areas like Finland, northern Sweden, and the Laurentian upland of north central and northeastern North America have extensive areas of exposed bedrock, sparse mantle rock, and myriad lakes. In such areas agricultural possibilities are limited and forest represents the most economical use of the land.



Upper section shows scoured glacial plain, lower section illustrates a glacial drift plain.

In a wide belt near the margin of the ice-covered area, deposition prevailed over erosion; and with the melting of the ice its rocky burden was left as a mantle of varying thickness (lower Illus. p. 43). A large area in North America, between the Great Lakes and the Ohio and Missouri rivers, and including most of New York and all of New England, was covered by a heavy mantle of glacial debris. In Europe, similar material forms the surface of much of the northern part of the continent and all but the southern part of the British Isles.

Glacial debris is of varied content. It may be coarse or fine, dropped by the ice directly or by the waters which issued from the ice through melting. The mantle rock deposited by the ice is commonly referred to as *glacial drift*. It can easily be distinguished from alluvium, for alluvium is well sorted according to the size of its particles, while glacial drift is an unassorted mixture of rock fragments of all sizes.

Sometimes glacial drift is loamy (a mixture of sand, silt, and clay), with large and small boulders scattered through. In areas of old drift, most of the coarser materials have been broken down by weathering, and rich, easily tillable, loamy soils may have been developed. In other places the drift may be very stony and sandy, especially in areas of more recently deposited drift. Sandy glacial areas occur in northern Michigan, northern Wisconsin, and northern Minnesota. From an agricultural point of view such regions are distinctly marginal. In New England the numerous glacial boulders made tillage difficult. The colonial farmer with unending patience picked out the stones, large and small, and piled them into mile upon mile of stone fence. These stone fences are still one of the most characteristic elements of the New England landscape.

Photo by N. A. B.

Glacial morainic topography in southeastern Michigan Note irregular, hummocky hills left by melting of ice with consequent deposition of contained rock debris

Wherever the front of a glacier remained stationary for a number of years, either at its farthest extent or at a temporary pause during the recession of the glacier, unassorted rock debris accumulated in sizable irregular ridges parallel to the front of the ice. These ridges, known as *terminal moraines* and *recessional moraines*, stretch for miles across the lands of former continental glaciation (Illus. above). Such moraines run the length of Long Island, New York. The blocking of drainage by such moraines has resulted in the development of numerous lakes.

Conclusion. We have outlined briefly in this chapter the character of the earth as a whole and of the lithosphere in particular. We have glimpsed the numerous varieties of bedrock and their geographic significance as the foundation of land forms. We have touched upon the major land forms, their reduction by weathering and erosion, and the redeposition of their weathered products as another set of land forms offering varied economic problems and opportunities.

In a book on economic geography the physical factors can be dealt with only briefly. Readers interested in a fuller understanding of this phase of geography will find that there exists an abundance of material to which they can refer for further reading.

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Chapter Four

ECONOMIC ACTIVITIES AND THEIR PHYSICAL BACKGROUND

It seems likely that ancestral man began his upward climb into the realm of thought and planning while he was primarily a gatherer of the products of Nature. He thus responded to the urge common to all life, the urge to live. To provide subsistence is the primal necessity of life, and probably the first activities of man were directed to this end by hunting animals which would when killed provide meat for food and skins for raiment. Fish in the shallow waters along seashores and in inland streams would readily be suggestive of a food source to hungry man. These were undoubtedly the earliest forms of activities whereby man sought to assure himself of food and raiment, and therefore they may be termed the earliest economic activities of man. Broadly defined, economic activities are the various pursuits whereby man makes his living and earns the means for satisfying his social needs

From the elemental activities of gathering, hunting, and fishing without equipment other than such as were provided by Nature, man has through the ages gradually developed the complex activities of the modern industrial world. Hunting and fishing still are important human activities but are no longer defined as merely subsistence pursuits; now they range from sports and recreation to highly commercialized factory-type industries, but even so they make up but a small fraction of the economic activities of the people of any modern industrial nation.

At first glance one is tempted to think that any classification of the diverse economic activities is likely to be futile. And yet, if a general perspective of the activities of the modern world is to be realized some systematic plan must be worked out. Closer study will reveal that man's economic activities can be organized into a relatively small number of main groups or divisions, with each division having a "golden thread" of common interest extending through it. It will also be found that each group operates within rather closely defined limits set partly by man and partly by Nature. One of the functions of geographic study is to describe and to evaluate the interrelationships of economic activities and the natural conditions under which they operate.

Commercial hunting and trapping. North America, on the advent of the white man, was a hunters' paradise. Besides offering millions of animals of the eatable kind, it was teeming with fur-bearing species. The early fur traders were the first white men to penetrate this continent in search of the prized pelts. Trapping has been carried on rather ruthlessly ever since and is still the only means of livelihood for some in the wilds of Canada. In the United States, however, trapping is becoming more and more an avocation and a pastime for youngsters.

The greatest hunting ventures are now a matter of history. In the beginning of the nineteenth century whaling ranked among the foremost hunting expeditions. In 1850 more than seven hundred American ships scoured the oceans for this prized mammal. Today whales are relatively scarce in northern waters. Sealing was likewise once an industry of major importance. In its heyday it was carried on so ruthlessly that the seals were virtually extinguished within a century and a half. Whereas millions of seals formerly disported themselves on the shores of Antarctic seas, today they are so scarce there that commercial sealing has practically ceased. The northern seal barely escaped a like fate. Thanks to the United States government, unscrupulous killings were stopped just in time to spare the seal from the fate of the dodo. This was accomplished through the initiative of the United States with the co-operation of Canada, Russia, and Japan.

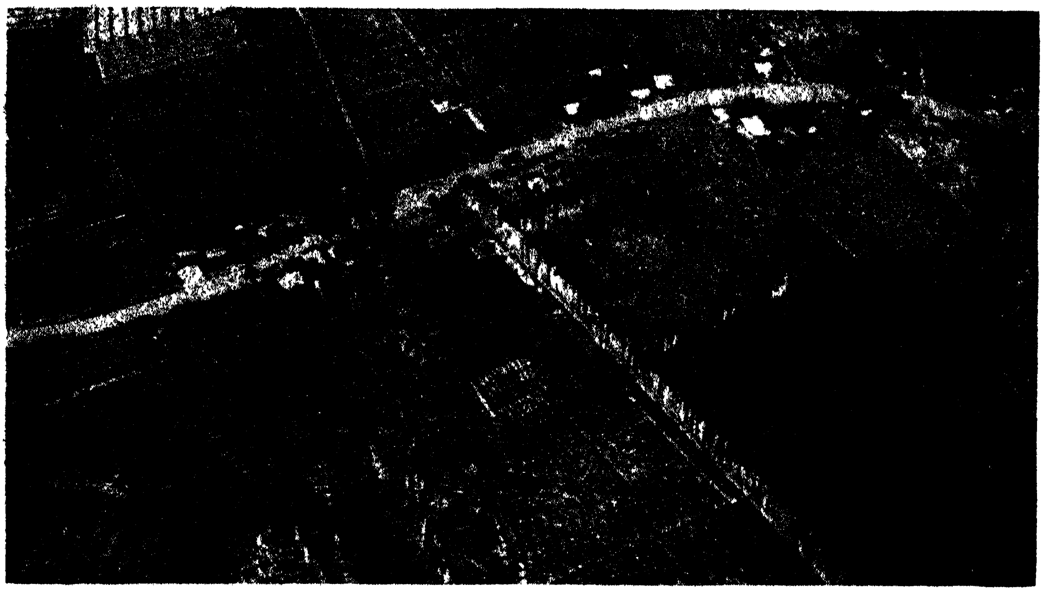
As late as 1850-1870 the Great Plains of the Middle West from the Dakotas to Texas provided pasture grounds for countless herds of American bison. These were decimated ruthlessly by no higher motive than the lust to kill. For generations the bison had been hunted by the Indians for their supply of meats, fats, and skins, a laudable economic activity for subsistence; but when white man came with guns the hunt ceased to be an economic activity, it was merely slaughter.

Fishing may be divided into inland fishing and marine fishing. The former connotes fishing in inland waters. The restricted areas of such waters and the vigor with which fishing is usually carried on leads to rapid depletion of the fish population. This has brought about the necessity of stocking such waters through activities of governments and private individuals. In the United States, millions of young fish are raised yearly in hatcheries for distribution into lakes and streams. Various European countries engage in this same procedure of artificial propagation. With as great diligence and care as we raise fine cattle or poultry, even private fish culture is an important industry in some parts of China and Japan, where fish are produced in areas which otherwise would be economically useless. Much-needed food is provided in this manner. On the other hand, vast fishing enterprises on a commercial scale are carried on in the middle and higher latitudes. The most prominent fishing grounds are those of the North Sea, the fishing grounds off the coast of New England and Newfoundland, and the seas adjoining Japan. (See the Physical Map of the World.) These are discussed in Chapter Seventeen.

Agriculture. Agriculture is perhaps the oldest systematic pursuit of civilized man. Regardless of whether early man was first a herder of beasts or a tiller of the soil, such activities inevitably led to a degree of co-operation and group activity. Agricultural activities refer to all of man's labors related to the cultivation of the soil and to industries which are directly dependent upon it, such as the production of livestock. These activities are prompted by one of two main purposes: (1) to supply local wants and needs, or (2) to furnish that which other people desire. The first-named type of activity is termed *subsistence agriculture* and the latter *commercial agriculture.*

The term *subsistence agriculture* is a relative one and varies in significance as to time and place. Whereas all agriculture was of this nature in its earliest stages, today we find considerable variations because in most areas agricultural production is partly for local sustenance and partly for surpluses to be sold on the market, the proceeds to be used for purchase of other goods or services. Thus the farmers of the Corn Belt of the United States do considerable home butchering and home curing of pork and beef products for their own use; this aspect is distinctly one of subsistence agriculture.

On the other hand, the larger proportion of their crops of grain and forage are sold either as such or after having been converted into fattened livestock or into dairy animals and dairy products. This type of mixed agriculture is most widely prevalent in nearly all the food-producing areas of the world. In some areas of high density of population, as in parts of China and India, farmers consume directly with but little processing all the grain they produce; they cannot afford the luxury of feeding edible foodstuffs to animals to be converted into meat, and their total production is so low that there is never any real surplus to be stored or exchanged for other goods. These are among the most severe famine belts of the world. Subsistence agriculture is typical of agricultural areas that lack means of exchange. It is characteristic of pioneer conditions where people are few and transportation facilities wanting, and of areas of extreme density of population where total production of foodstuffs must be used directly in man's diet.



Courtesy American Geographical Society. Photo by J. L. Rich

Market gardens and orchards on delta of Rio Parana, near Buenos Aires. What do the small fields, closely spaced, indicate as to intensity of land use?

Modern transportation facilities by land and sea and air have widened the horizon of trade and commercial relations. The corn farmers of Iowa, the wheat producers of Alberta, and cotton growers of Mississippi exchange their products for coffee, cacao, bananas, spices, and other agricultural products of the lower latitudes. Each region may now specialize in the production of agricultural commodities particularly adapted to its environment and exchange surplus products with far-away lands, mainly for products of city enterprises such as factory goods, drugs, and medical services. Even the silk producers of Japan and the tea producers of China, who raise most of their own food products, are within the orbit of commercial agriculture.

Commercial agriculture bespeaks specialization in the production of agricultural products and in the exchange of surplus products for the many other needs of the producers. Agriculture in most of the progressive, industrial nations is now on this basis. The potato producers of Maine, the cranberry producers of Massachusetts, the ranchmen of Wyoming, and the coffee producers of Brazil are but a few illustrations of this type of activity (Illus. p. 48).

Forests as resources for industry. Civilization owes a great debt to the tree. Multitudes of instruments and devices are easily made from it to till the soil and to kill the beast or the human enemy. Seaworthy ships could not have been made by our forebears without the products of the forest. The fruits of trees are a valuable adjunct to the diet of man. It is sometimes assumed that forest products, particularly wood, are becoming less important. This impression, however, is erroneous. Our paper mills are continually making greater demands for wood pulp. New and novel demands for wood are arising which more than offset the declining use of lumber for building material and other purposes.

Courtesy Caterpillar Tractor Company, Peoria, Ill

A phase of logging Caterpillar tractors serve to keep logs moving in shallow water streams where rock bottoms make use of tractors practical.

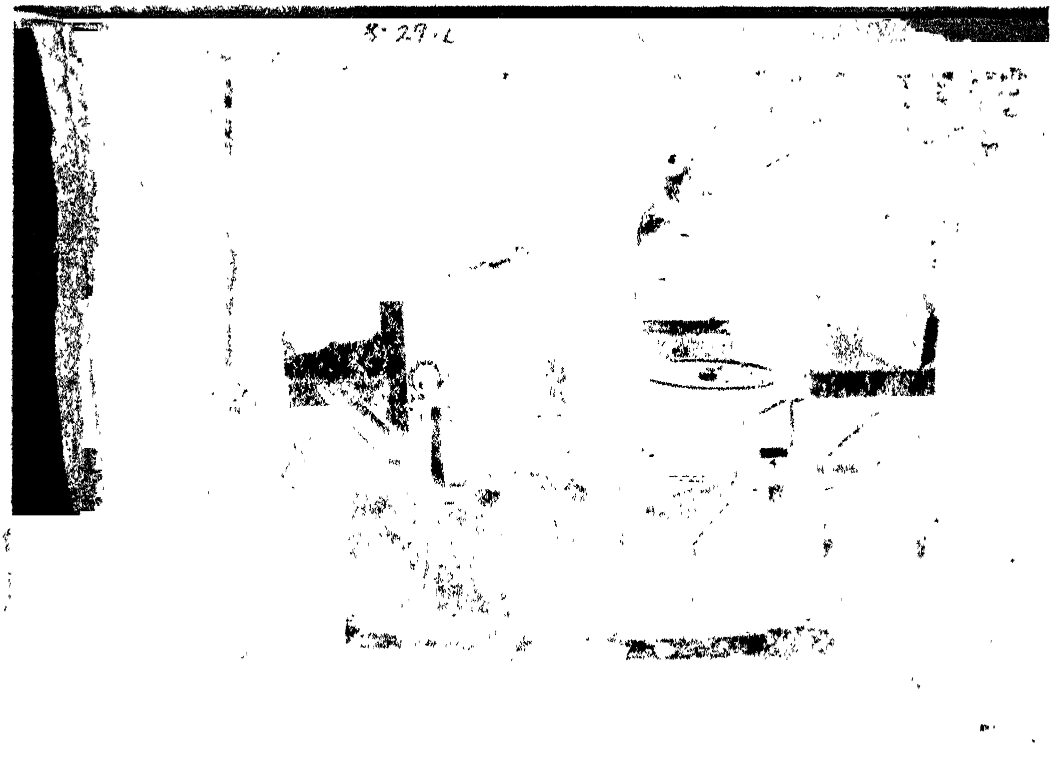
Forestry may roughly be divided into logging and the search for forest products. The more important trees for logging purposes are cedar, mahogany, teak, oak, pine, fir, and spruce. The more popular forest products are gum, latex, cork, herbs, rosin, tannin, wild fruits, and nuts. In addition, let us not forget that wood itself is the most important forest product.

Forests generally occur in the more humid portions of the earth. The tropical rain forests of Central and South America, Africa, southeast Asia, and northern Australia represent the most heavily forested areas of the world. So many species of trees find these regions favorable for growth that the resulting mixed stand discourages extensive forest exploitation in those warm and humid lands. Poleward, where climatic conditions are more severe, fewer species survive, and solid stands of the most fit result. This is a factor of high economic significance in logging and lumbering operations.

Mining and mineral products. The extractive industries refer to the enterprises which withdraw irreplaceable natural resources from the earth for human use. Since many minerals are limited at or near the earth's surface, local depletion is inevitable.

Mining, quarrying, and drilling are the more common methods of gaining the desired mineral substances. Mining may be carried on either by surface operations or by underground workings. Iron ore is so abundant at or near the earth's surface that in many places it is obtained by steam shovel operations. Coal, although exposed in many regions, is usually obtained by the use of shafts and tunnels. Metallic ores, such as copper, gold, silver, lead, and aluminum are derived by either or both of these methods.

The removal of stone, clay, sand, gravel, or other rock material from its natural position is termed *quarrying*. Another group of minerals, such as petroleum, natural gas, sulphur, and salt are obtained by drilling and pumping. The operations of oil wells, quarries, sand and gravel pits, and clay pits all are forms of mining and all are extractive industries.



Courtesy Educational Department, Bituminous Coal Institute, Washington, D C View from Gay Mining Company

Mechanical methods of mining coal are now common. Note the electrical drill being operated to make holes in the bed of coal. A prominent hole is indicated by the dark spot at the left of the operator. The loose coal in front of the right wheel is caused by undercutting the seam at the base. Carefully prepared charges of explosives will be inserted into holes being drilled and the face of the coal seam will be blasted so skillfully that very little fine coal will be produced.

The mineral resources, the raw materials upon which the development of most of the extractive industries depend, are scattered widely over the earth in spots or areas of limited extent, not in broad zones as is generally the case with agricultural resources. Exploitation of mineral resources therefore follows a pattern of irregular design characterized by districts of intense activity and concentration of population separated by large spaces of little activity and sparseness of population. Illustrations of these conditions occur on every continent; as typical examples may be named the coal-mining district of Kuznetsk in the Soviet Union, the petroleum fields of Persia, and the copper ore producing districts of Chile.

Manufacturing and repair. Manufacturing refers both to enterprises in which raw or semifinished materials are converted into finished or more nearly finished products and also to tasks in which labor is applied to the construction or repair of things. Converting iron ore to pig iron is a form of manufacturing which uses natural raw materials and furnishes a semifinished product. This semifinished product, pig iron, then becomes a raw material for further processes of manufacture, such as the making of cast iron, malleable iron, and steel. These products, in turn, are the raw materials used in other industries wherein the iron or steel is fashioned into shapes needed in instruments, machinery, tools, and tubes of various kinds.

Manufactures are generally classified as "heavy" and "light" types. In the heavy manufactures the ratio of skill and effort expended in proportion to the volume, weight, or value of the product is low. For instance, in the construction of a freight car, the amount of skill and effort applied to a unit of weight or volume is much less than in the construction of watches and clocks. Again, the sawing of lumber represents a task of less skill than does the manufacture of typewriters and adding machines. The latter activities represent light manufacturing. The distinction between heavy and light manufactures is a relative one. The terms may also be applied to industries of the same type, in which similar materials are manufactured. In such cases weight of product and skill in workmanship are the criteria. Cotton goods, for instance, may be of the heavy or the light kind, the former term designating coarser, rougher, heavier, and cheaper goods, and the latter term indicating light and more costly goods.

Generally speaking, the labor in heavy manufactures is of a less specialized, less technical nature than it is in light manufactures. This is an important factor in the mobility of these respective industries. Heavy manufacture, with its less skilled labor requirements, can shift more readily as the exigencies of a changing industrial world require. Light manufactures, on the other hand, tend to remain where skilled workmen reside. Strange as it may seem, the latter are relatively immobile.

Manufactures are also referred to in terms of manner of use to which they are to be put as *consumer goods* and *capital goods*, the latter often being termed *durable goods* as well. In the first-named category, processed foodstuffs are the most direct and well-known examples, including such items as breakfast cereals, canned fruits and vegetables, and meat-packing products varying from steaks to corned beef. Consumer goods also include textiles and wearing apparel because of the relatively short life of such goods when subjected to normal use. Capital goods, on the other hand, include tools, machinery, and other equipment designed to promote production and income. Manufacturing concerns must always set aside a part of their income to be used in maintenance and improvement of their plant. The term *durable goods* is widely used, perhaps in a less technical sense, to include items of home equipment used principally to add to the comforts of living; typical examples would be musical instruments for home use, radios, refrigerators, and table and kitchen ware. In a stricter sense, most durable goods would be included under capital goods as well.

The building industry. Shelter not only is one of the primary human needs but also is a conspicuous part of the geographic landscape. Among most primitive people the need for shelter is satisfied with huts of poles covered with straw or skins, requiring only a day or two to construct. As techniques and standards have led to demands for larger, more permanent houses, building has become a specialized industry with division of labor among carpenters, bricklayers, concrete workers, glaziers, plumbers, electricians, painters, and others, whose work extends over several months in the construction of the average residence.

Our modern homes of wood or brick are the outgrowth of thousands of years of development in the Old World. Egypt and Babylonia used sun-dried bricks (adobes) over 5,000 years ago, and one of the earliest labor complaints on record came from the enslaved Hebrews forced by the Egyptians to make adobes. Today mud is still the standard building material for large areas of the earth, such as dry portions of the Middle East and Latin America where the climate does not support forests and the brick tradition is strong. Burned bricks, made from a mixture of clay, sand, and ashes, were widely and early used in the wood-deficient Mediterranean lands, and today are much used in areas of abundant coal or cheap transportation.

Wood, the principal construction of the American home today, was used in the forested portions of Europe, first in the form of logs and later in the form of sawed planks. The settlers on the Atlantic coast of America brought with them their wood-using techniques and found abundant raw material in the eastern woodland of the New World. Both in Europe and the United States burned bricks are now much used for building because of their greater resistance to decay and fire. Most of our modern "brick" houses, however, are fundamentally wooden houses with a veneer of bricks instead of paint. Stone has always been used to a certain extent, though it requires special skills and usually costs more than other building materials. It is extensively used for public display works such as the Washington Monument, the Great Pyramid, and the Supreme Court building.

The most massive modern structures being built today, the great water-storage dams, are made of concrete, a material that has long been employed for special uses such as building cellars and finishing. Steel reinforcing adds to the strength of concrete structures. The modern skyscraper, factory building, or large apartment house has a framework of steel and a finish of cement or stucco. Though concrete and steel are essential to large modern buildings, they have not yet made much headway against the humble traditional wood for ordinary residences.

Transportation and communication. Transportation and communication activities are the many enterprises which effect the conveyance of goods of commerce, and also of man and his messages. The terms should be interpreted broadly enough to include the maintenance of the many plants which are necessary for these operations.

The means of transportation and communication have changed so greatly from time to time that enumeration is neither feasible nor necessary. Within historical times, slaves furnished the motive power for crude vehicles and ships. (Illus. A, p. 53.) Even now, as in parts of China and Japan, human beings are used to pull or carry loads—coolies with their rickshaws are well-known examples. The use of beasts for motive power marks an advance over the human method of transportation. For this purpose horses, asses, cattle, camels, dogs, llamas, elephants, and reindeer are commonly used. However, the most advanced means of transportation utilize power obtained from mineral fuels or from falling water. By means of steam, gas, or electric engines, tours formerly requiring years and months of time can be completed in days and hours. (Illus. B, p. 53.)

The importance of transportation is such that most of our metropolitan areas would be reduced to serious shortages in less than a week if the importation of foods should cease. Rural areas would likewise be reduced to a subsistence level if transportation were discontinued.

Trade and commerce. Trade and commerce are closely related to transportation and communication. Where the latter exist, agencies must be instituted to bring

Courtesy Dr George B Cressey, Syracuse University

(A) Primitive transportation, a common sight in parts of China where wheelbarrows for freightage of goods are still in use although automobiles may be seen at the same time on a few of the roads

Courtesy Eastern Airlines

(B) Modern passenger planes are swift-moving, safe, and dependable By inquiry learn hourly rate of speed, altitudes of flight, and passenger capacities of planes now in use about an orderly exchange of the various products that are available. The exchange of goods—that is, buying and selling—and the agencies which in part render possible or encourage such activities are included in the expression *trade and commerce.* Among the more common institutions of this kind are import and export houses, produce exchanges, shipping agencies, wholesale establishments, grain exchanges, banks, insurance companies, and retail businesses.

Professional and public services. Positions in professional and public services require either special training or public trust. Scientists, engineers, educators, doctors, lawyers, religious workers, and administrators are the outstanding workers in these fields. Their professions are noted for the public leadership they provide, and their trust is a serious one. It should be a matter of public concern to retain them at the highest possible standards.

Domestic and personal services. No classification of occupations would be complete without mention of the distaff side of life. A poet once said, "Man works from sun to sun, but woman's work is never done." It is submitted herewith that the work of woman has been and is of such significance that no writer needs to attempt to appraise its importance.

Under personal services are listed occupations in homes, hotels, laundries, cleaning and dyeing institutions, and many others.

Relationship between economic activities and the natural environment of any given area. Industrialization has not rendered man independent of his environment. In advanced society he may not be so directly dependent upon certain local aspects as is the case in the primitive state of development, but on the whole his interest in the problems arising from environmental factors is greater. As illustrations, we may recall the organized exploratory search for new petroleum fields, new deposits of potash, nickel, and manganese, and now the world-wide search for uranium. The iron and steel industry centered around our Great Lakes would suffer a body blow if either the iron ore or the coal should be depleted. Again, the distribution of iron ore over the world and its utilization are of great significance to the American iron and steel industry. Great new development elsewhere might readily lead to reduced foreign demands and therefore necessitate restriction of domestic production.

In the realm of agriculture the vital factors of moisture, temperature, winds, sunshine, and length of growing season are effective in high degree on all lands. Upon those factors depend the possibility of one, two, or three crops per year, and likewise the kinds of crop that will be produced, whether barley, wheat, corn, rice, or cacao. Land form is likewise important because the use to be made of the land is directly affected by it; for example, farming under irrigation and the use of terraces to reduce erosion and to maintain tillage agriculture. In all these instances the factors of the physical environment are broadly dominant.

Nevertheless, the human factor in the development of industrial activities must not be underestimated. Man may use the resources constructively or he may allow them to remain dormant, as he has done, for ages. Man himself is a potent geographical factor, as evidenced by his clearing of forests, replacing of prairies with fields of grain, impounding of waters to form lakes, tunneling through mountains, and changing the courses of streams. The presence of large cities attests the extent to which man may alter the details of environment; there the details of the original natural landscape are masked by the streets and structures built by man.

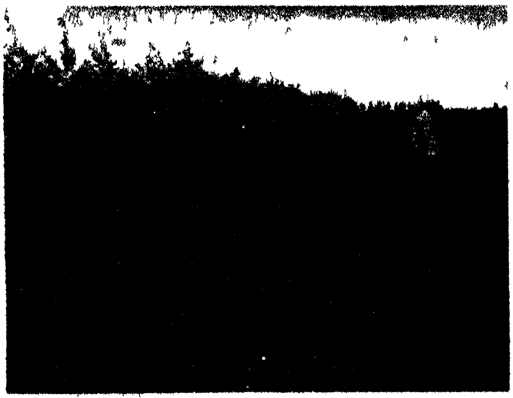
It should not be presumed that human adjustments in any place are perfect. New resources or additional ones are being discovered almost daily in some parts of the world. As their values become known, adjustments are set in motion whereby the rewards of exploitation may be secured. Within certain broad limits, therefore, it is evident that Nature must provide the resources and the conditions for exploitation whereby man may, by intelligent activity, satisfy his needs and desires.

Relationship of natural landscape to the cultural landscape. The natural environment in any given area is usually well reflected in the features of the *natural landscape.* By that term we refer to the land as it is with its various kinds of surface forms, its streams and lakes, its natural vegetation, and its native fauna. Through man's activities, changes are brought about, such as plowing up the sod, cutting down the forests, planting various crops, straightening or deepening stream channels, constructing irrigation projects, and preparing grades for roads and railroads. In these and in other ways the natural landscape is changed in its details and rendered more adaptable for use by man. By these means a *cultural landscape* is created. (Illus. pp. 55 and 56)

The true natural landscape can be seen only where man has made no changes, such as construction of roads, fences, or houses, and where he has not visibly reduced or changed the vegetative cover Similarly the cultural landscape in its fullest sense implies complete fade-out of the features of the original, natural landscape and its replacement by cultural features so complete as to hide even the fundament upon which they stand. Since for most of us these extremes are not commonly available, we must bear in mind that usually the landscape before us is a combination of both. the cultural features have been superimposed upon the natural in varying proportions In grazing areas such as those of the southwest or in parts of the Great Plains the principal culture features are the fences, widely spaced houses, and a few trails and roads In farming areas man's imprint upon the natural landscape is more effective. there,

Courtesy U S Bureau of Reclamation, Washington, D C

Natural landscape in unirrigated section of Nevada Note that there is absence of any human activity Scattered brush due to low rainfall cultivated crops have replaced grass and forest; farmsteads are close together and connected by telephone and perhaps by power lines; and roads lead to near-by towns. With all these changes in detail, the general topography remains virtually unchanged as to flat lands, hills, and valleys. In the cities, however, man's structural activities are generally dominant. Hills have been reduced, grades lessened, and streets and buildings conceal much of the original landscape.



Courtesy U. S. Bureau of Reclamation, Washington, D. C.

Cultural landscape due to irrigation, same section of Nevada as preceding picture. Trees at left were planted and are maintained by irrigation as is the alfalfa field in the foreground.

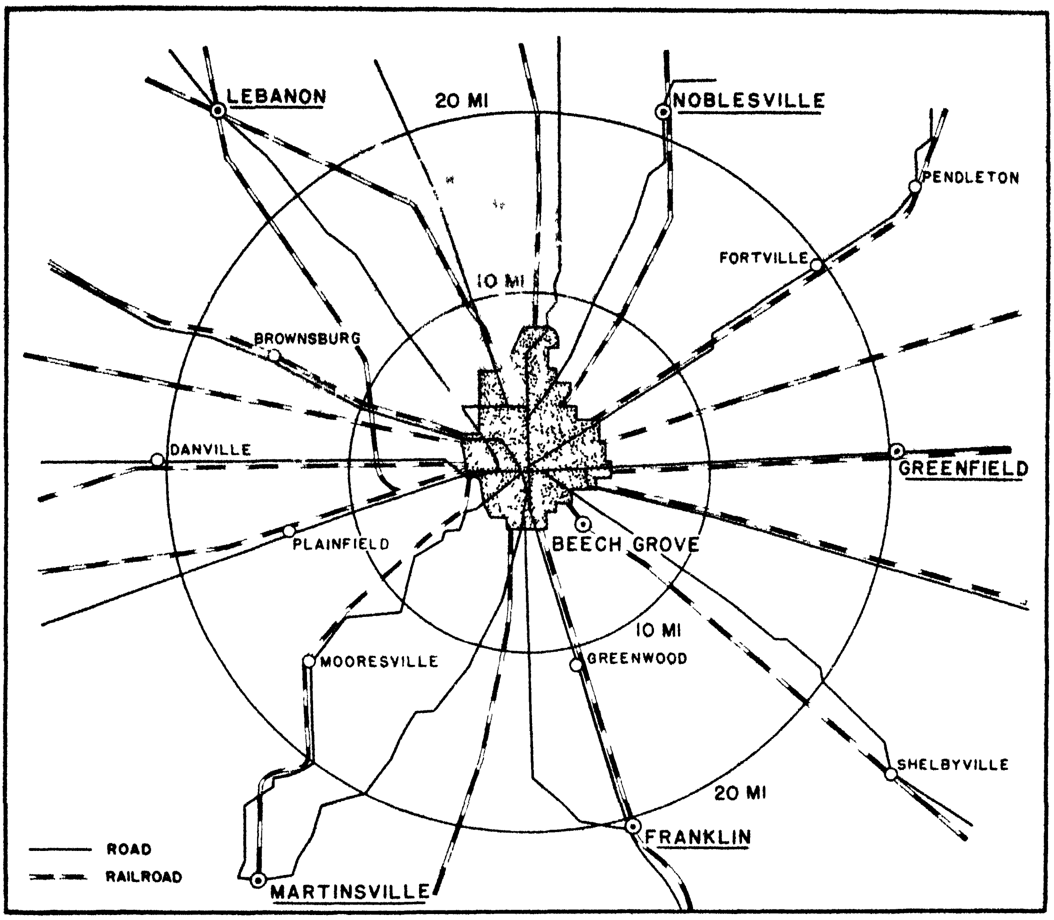
In order to understand and appreciate the relationships of the cultural to the natural landscape, one must have some degree of mastery of the facts involved, a mastery which can be reached best through a definite and systematic organization of the essential facts. It is suggested therefore that the facts pertinent to the natural landscape be summarized rather definitely into six major groups: (1) location, (2) climate, (3) land forms, (4) water bodies, (5) land content, or soil and minerals, and (6) native flora and fauna. If each of these topics is adequately treated for any area on earth, any intelligent person should be enabled to visualize the natural landscape of that area.

Location. The location of any place under consideration is not only a basic fact in itself, it is also a factor of high geographic importance. Regardless of whether areas are large or small, whatever may be true of their land forms, types of climate, soil and mineral resources, native plants and animals, or man's activities, location is important in understanding the occupations. Location in itself, regardless of all else, is often a foremost factor in the possibilities of the growth of a city or in the success of a business. For example, it is clearly recognized that small towns located near large cities rarely grow into important trading centers because of being overshadowed by their greater neighbors. Even in matters of current events, location is always given in the presentation of the story in order that the reader may know where the scene of action is laid. Such information is valuable in interpreting the significance of the event and in understanding its causes and consequences. Location, therefore, should be carefully stated in connection with every geographic description, and in most cases it is equally important in economic reports on business enterprises. (Illus. p. 57.)

Water bodies. That bodies of water are important environmental features is evident to all. What small boy in a country district has not felt the spell of the water hole or has not experienced the thrill of catching diminutive members of the finny tribe which later, as the stories were re-told, took on greater and greater proportions?

The indirect influence of water bodies pervades all land areas of the earth. The water which falls as rain must have come from the sea, whence it rose as water vapor and made the voyage from source to destination in a gaseous state. Water bodies modify temperatures over sea and land, in greatest measure, of course, along coastal areas, but in some degree also in the very hearts of the continental land masses. In addition to the effects of large water bodies upon the climate, there are important geographic relationships to transportation and industry. Ocean-borne commerce makes the whole world kin. Through it we are enabled to sell our goods in all parts of the world and in turn to enjoy the products of distant lands in our own scheme of living.

The influence of water bodies as a feature of our environment is not limited to the great seas and oceans. The small lakes which are peppered over the land in many areas, and the networks of streams which cover the land nearly everywhere, are directly effective in every community. As water supplies, as power resources, as drainage channels, or as transportation routes, they are of economic significance to every community. Furthermore, the lakes, ponds, and streams furnish facilities for fishing, boating, canoeing, skating, and other recreational activities which represent social assets equaling or surpassing their economic values.



Indianapolis and surrounding towns Railroads and main roads all center upon Indianapolis. The influence of the city has precluded the growth of towns within a considerable radius, except those of a suburban character

Land content. The content of the land should be thought of as consisting of two major groups: mineral deposits and soil material This content is responsible for the types of human activities in many regions of the world. Inasmuch as this topic is fully developed in later chapters of this book, it needs but mention here.

Native vegetation. Native vegetation refers to the natural plant growth which mantles the earth's surface. In some places the native vegetation is quite simple, as in parts of the southern pine forests, where large areas are made up of only a few species of plants. In other places it is exceedingly complex, as in the low-latitude jungles and in certain sections of the Great Plains. Inasmuch as most plants are practically immobile—that is, they cannot move about—they must depend entirely upon their immediate environment. Where a number of varieties are present, such species dominate as are best adapted to the growth and maintenance factors of that locality. These factors are soil, temperature, rainfall, drainage, and sunlight.

Crop plants cultivated by man are not included under the term *native vegetation.* Wherever man breaks the sod, cuts the forest, or stirs the soil and cultivates crops, he creates an artificial, a cultural, landscape. Thus, plantations devoted to rubber, cotton, cacao, or coconuts, and fields planted to corn, wheat, tobacco, or sugar cane are not clothed in native vegetation, but are farmed areas constituting a phase of the cultural landscape.

Native animal life. The native animal life of any region includes all of the wild life of the area; that is, not only the four-footed animals, such as are ordinarily thought of, but also fish, birds, snakes, and insects. Since animals subsist upon plants or upon one another, the wild life of any region is, in large measure, a response to the environment. Yet the animal life is not quite so directly and intimately a reflection of the environmental conditions as is the plant life, because animals have the power to move about, some having developed this ability to a high degree. Birds and some species of fish rank foremost among those with exceptional abilities of migration. Among the land animals, the fleet-footed kinds, such as the antelope, the deer, and the rabbit, show greatest ability in moving swiftly and covering distances. Hence they can overcome environmental handicaps by escaping adverse conditions at various times. In contrast with these species are others whose power to roam is limited to narrow confines. They can progress but slowly and only within restricted conditions of environment. Examples are found in the hippopotamus, characteristic of some of the rivers and adjacent marsh areas of Africa, and the alligators and crocodiles, which, although fully equipped with powers of locomotion, cannot travel great distances from their water habitat. Many of the insects have small capacities for flight. These are the kinds of animal life which give the clearest and most definite evidence regarding the environmental conditions which prevail within an area.

The native animal life may be classified with respect to its relationship to man. Some animals are used for food, whereas others are valuable only for the materials which they furnish for clothing or shelter purposes. Still others have almost no value to man, but present a negative relationship in that their presence is mostly harmful.

Climate. Climate is usually defined as *the average of weather conditions prevalent at any place or area,* with due recognition of the fact that deviations from the average are often of equal or even greater significance to man. Since the weather elements of major importance include temperature, humidity, winds, precipitation, and sunshine, climate is a résumé of their averages, and as such it is recognized as one of the most effective geographic factors. It is generally conceded that climate is directly connected with the health, happiness, and well-being of man. Some climatic conditions are energizing, whereas others are enervating. Climate not only affects the health of man, but it also influences many of his activities, since it often virtually determines where a certain kind of domesticated plant or animal may thrive best. In order to comprehend the economic life of people in other parts of the world, one should know the climatic conditions under which they make their living. We can always understand better what goods people produce and what they need to buy if we have knowledge of the climatic conditions under which they live.

Climate and agriculture. Agricultural production responds directly to climatic factors such as temperature, rainfall, sunshine, and wind, and thus the crops which can be grown in any particular area depend largely upon the type of climate which prevails there. Where the climate is favorable, potential agricultural production may be high; where unfavorable, productivity may be so low that agriculture is impossible unless the climatic handicap can be overcome by artificial means as, for instance, overcoming aridity by irrigation. (Illus. p 56.)

The intimate relationship between climate and food, shelter, and clothing is generally recognized, and illustrations of this relationship can be found everywhere. In cold lands the houses generally are sturdily built with thick walls, solid foundations, and elaborate heating systems, whereas in warm lands such features are ordinarily wanting. The dwellers of cold lands clothe themselves in hides, furs, and woolens, while those of warm lands wear clothes that are light and airy. People in the arctic regions consume great quantities of fats and do so with evident relish, whereas those in the tropics live on much lighter diets, placing greater dependence upon fruits and vegetables.

Climatic dissimilarity as one of the fundamental bases of trade. The significance of climatic differences goes beyond differences in food, clothing, and shelter, however important these may be. That the people of the tropical lowlands grow and eat bananas and coconuts in abundance may interest us, and we may even feel envious at times over their good fortune in this regard; but the real economic significance of these facts is that, through surplus production and efficient transportation, bananas and coconuts have become available in regions where they cannot be produced, *and thus they have become commodities of world commerce.* The same holds true for a great number of other agricultural products. Throughout the industrial world we draw upon areas near and far for supplies to be used as food and as raw materials for manufactures. Not a day passes but that we are beneficiaries of the products of foreign lands, and daily our goods are shipped abroad to serve the needs of other peoples.

Differences in climatic conditions are among the fundamental causes of differences in production, and besides, give rise to varying needs and desires. In these differences lies one of the most fundamental bases of trade, both intranational and international. For example, the farmers of Iowa produce a surplus of agricultural products, the sale of which enables them to purchase manufactured goods from the east and citrus fruits from Florida and California. Canada produces a surplus of wheat, lumber, and furs and imports products of more southern climates; the people of Central America are enabled to buy the products of the north if they can sell their surplus of bananas, coffee, and coconuts. Thus, in large measure, the currents of trade flow in response to climatic differences. If we desire to comprehend the fundamental bases of trade, we should not neglect to study the climatic factors involved.

Chapter Five

THE CLIMATIC FACTORS

“Everyone talks about the weather but nobody does anything about it.” This oft-quoted statement by Mark Twain concisely expresses the interest which most of us who live in the middle latitudes have in the daily weather. This widespread interest, so general as to be taken for granted, is obviously due to the sudden changes which are characteristic of our weather and the great importance of those changes to our daily activities. But our interest often is more profound than is indicated by the trifling remarks we make concerning the weather conditions of today and tomorrow. When planning visits to other states or countries, or if contemplating a change of residence, we are likely first to inquire how cold the winters are and how warm the summers, whether it rains much or little, whether sunshine or cloudiness prevails. In other words, we seek to inform ourselves concerning the climate of our new place of abode.

Weather and climate. Whereas the study of the weather—meteorology—deals with the actual atmospheric conditions which prevail at any given time, the study of climate—climatology—deals with the averages of known weather conditions characteristic of a given area, as well as with the frequency of significant deviations from those averages. Thus the climate of a locality can be studied adequately only if records of its elements—such as temperature, precipitation, winds, and so on—are available for many years. Long-time records are especially necessary in the middle latitudes, where not only the changes in the weather from day to day may be great, but where there is considerable variation from year to year—mild winters and severe winters, hot summers and cool summers, occurring in irregular alternation and succession. In such regions, climate, as the average weather, often seems at first sight to be a somewhat illusory conception, and deviations from the averages may become as important as the averages themselves. For example, in subhumid and semiarid regions the variability of precipitation from year to year may climatically be even more important than the average annual total.

In large parts of the world, atmospheric conditions are not so changeable, and the principal characteristics of the daily weather may be foretold fairly accurately by reference to the calendar. It may be either always warm or always cold, always rainy or always dry, or wet and dry seasons may alternate with a considerable measure of regularity. Such uniformity of daily weather is especially characteristic of the lower latitudes. Under such conditions the weather generally is not the absorbing topic of conversation that it is with us, and records covering only a few years may suffice to give a quite accurate idea of the climate. However, even in these areas conditions vary in some degree from year to year. There are likely to be differences in the intensity and the length of the dry and the rainy seasons as well as shifts in the beginning and the end of these seasons.

In order to forecast the weather in the middle latitudes with some degree of accuracy, it is necessary to have available basic observations on temperature, atmospheric pressure, humidity, and other weather elements for as many places as possible. While formerly weather forecasting was of importance primarily to shipping and to agriculture, in recent decades air transportation has greatly increased the need for such basic observations, not only at the surface, but also aloft. In turn, the airplane, the pilot balloon, and the radiosonde have begun to furnish increasing quantities of observations at higher levels of the atmosphere which are indispensable for forecasting surface weather.

The number of meteorological stations in the world has increased greatly, not only in the middle latitudes, but also in the tropics. This increase in the number of records available has resulted in a better understanding of the climate of many parts of the world. Density of meteorological networks is, however, uneven. The United States, with adjacent portions of Canada, and Europe have the densest networks. In parts of South America, such as the Amazon region, in parts of Africa, the Near East, interior Asia, and the Polar regions stations are widely spaced and records often are brief and discontinuous. Thus our climatic information on different parts of the world is not equally reliable and complete.

Behind the complicated differences between weather and climatic conditions in various parts of the world lie some simple factors which govern the major traits of distribution of heat, pressure, and airflow. These factors are: (1) the sphericity of the earth, (2) the inclination of the earth's axis and its parallelism during the revolution of the earth around the sun, and (3) the rotation of the earth.

The major traits of the distribution of heat, pressure, and airflow are modified by such other factors as frontal development, distribution of land and water masses, occurrence of warm and cold ocean currents, and major relief features, mountain ranges and high plateaus, resulting in a complicated climatic pattern, which is represented in simplified form in the map Climatic Regions of the World, at the end of the book.

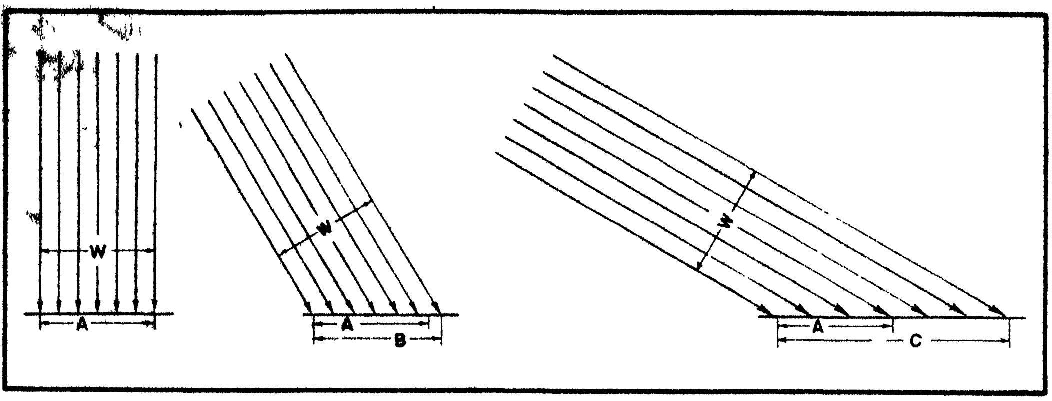
Major Factors Affecting Weather and Climate

Radiation and insolation. The sun sends out into space huge amounts of radiant energy, of which a very small fraction reaches the earth. Some of this radiation is visible, constituting light. The sun radiates most of its energy within the visible range, but some energy comes to us as ultraviolet radiation and some more as infrared.

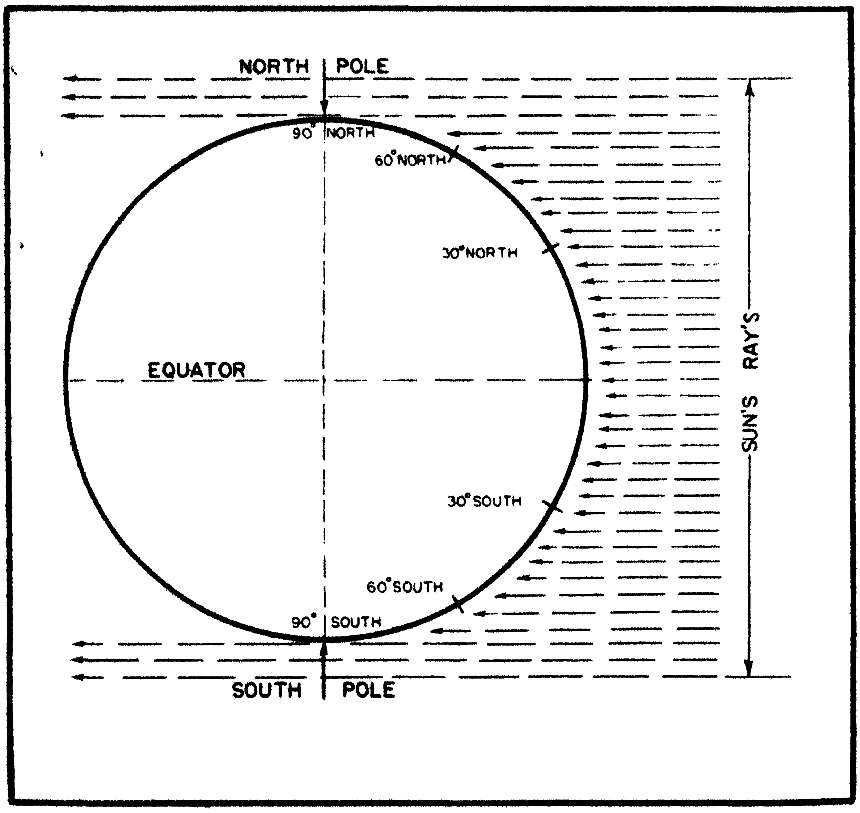
Insolation is the rate at which direct solar radiant energy is received on a horizontal surface. The insolation received at the surface of the earth depends upon the distance from the sun, the angle of the sun's rays, the duration of insolation, and the amount of energy lost while the rays pass through the atmosphere.

Insolation in relation to varying distance of the earth from the sun. The orbit of the earth's revolution about the sun is an ellipse rather than a true circle, and therefore the distance of the earth from the sun varies during the year. In December the earth is about 3,000,000 miles nearer the sun than in June, but this difference in distance is so slight in comparison with the average distance of the earth from the sun (about 93,000,000 miles) that it has no appreciable effect upon the amount of heat received daily during the year. Thus for ordinary purposes we may neglect differences in distance between the earth and the sun.

Insolation in relation to the sphericity of the earth. The great differences in the amount of insolation received annually at places near the equator and at places remote from it are due to the sphericity of the earth. A bundle of solar rays will illu-



(A.) Diagram of the sun's rays striking the earth vertically and obliquely. The diameters of the bundles of rays (w) are equal. Note that the diameter of the area over which the heat is distributed is greater in B, and considerably greater in C.

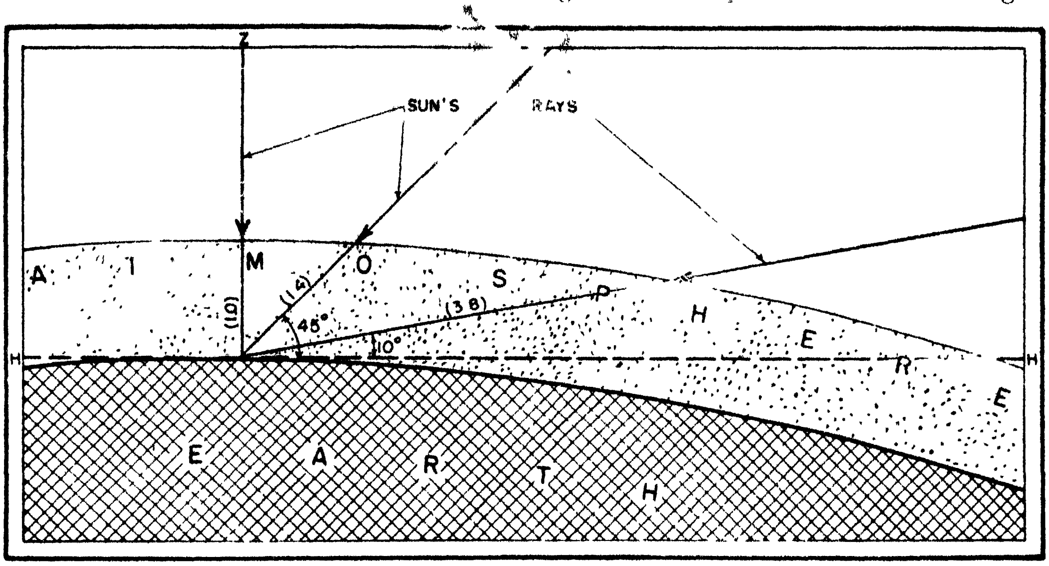


(B.) Sun's rays striking the earth in different altitudes (during equinoxes).

minate and heat a much smaller area if it shines upon a surface at right angles than if it strikes it obliquely (Illus. A, p. 62). If the rays are concentrated upon a smaller area, the intensity of lighting and heating is of course much greater than if they are dispersed over a larger area. Thus, the angle at which the rays of the sun strike the earth's surface is highly significant.

Near the equator the rays shine almost vertically upon the earth at noon, whereas in the higher latitudes the noonday rays strike the surface obliquely (Illus. B, p. 62). Since the diameter of the earth is exceedingly small in comparison with the distance the rays of the sun must travel, we may, for all intents and purposes, assume that the rays reaching us are parallel. During the equinoxes, in March and September, the sun's rays strike the equator at an angle of 90°, while they strike the 35th parallel at an angle of 55°, and the 60th parallel at an angle of only 30°.

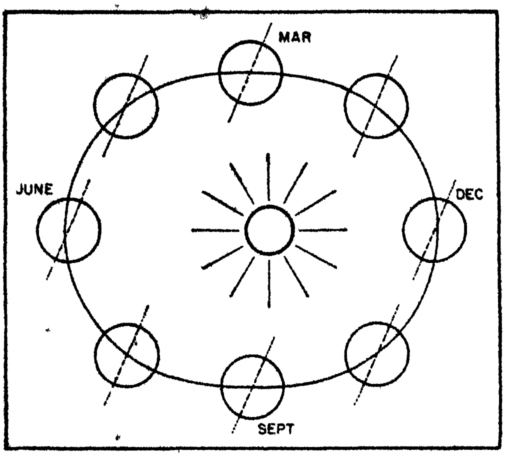
On their way through the atmosphere the sun's rays lose some of their energy through absorption, dispersal, and reflection. The farther they travel through the atmosphere, the greater this loss (Illus. above). It is evident that toward the poles, where the sun's rays cross the atmosphere more and more obliquely, the amount of atmosphere traversed and the loss of radiant energy sustained is much greater than near the equator. Of course, the same phenomenon can be readily observed every day. In the early morning, when the sun stands low in the sky, the sun's rays must traverse a great deal of atmosphere to reach the eye of the observer. At that time it is possible to look into the sun. At noon, with the sun much higher in the sky, it is not safe to do so. As a logical result of the foregoing facts, average annual temperatures on the earth generally decrease from the equator to the poles.



Differences in length of path through the atmosphere of the rays of the sun, when the sun is in the zenith, when 45° and 10° above the horizon.

Inclination of the axis and parallelism during revolution. The amount of heat which each spot on the surface of the earth receives varies during the course of a year. This is a direct result of the fact that the axis of the earth is not at right angles to the plane of revolution but is inclined toward it at an angle of 66½°. Both the inclination and the orientation of the axis are persistently maintained during the entire revolution of the earth around the sun so that in any position of the earth in its orbit the axis is parallel to all its previous and prospective positions. The North Pole of the earth always points toward the North Star, Polaris. This maintenance of orientation is called *parallelism of the axis.* (Illus. below.)

Seasons. Because of the inclination of the axis of the earth toward the plane of its orbit, the Northern and Southern hemispheres are alternately the more directly exposed to the sun's rays. On June 22 the position of the axis is such that the Northern Hemisphere is turned toward the sun. (Illus. p. 65.) Thus the rays of the sun strike this hemisphere's surface at relatively large angles, up to 90°. The high position of the sun in the sky makes for greater insolation north of the equator, and consequently the season is warm and is termed *summer* by northern people. During this same period the Southern Hemisphere is turned away from the sun and the solar rays strike it at comparatively smaller angles. As the sun stands relatively low, the effectiveness of its rays is less and temperatures are lower. It is the *winter* of the Southern Hemisphere.



Parallelism of the earth's axis. In any point of the orbit the axis of the earth is parallel to what it is in all previous positions.

Solstices and equinoxes. The inclination of the earth on its axis causes seasonal variations in the apparent positions of the sun in the sky. At noon on June 22 the sun strikes at an angle of 90° in the latitude of 23½°N. This parallel is named the *Tropic of Cancer.* Conversely, on December 22, the sun is vertically above the parallel of 23½°S., the *Tropic of Capricorn.* (Illus. p. 65.) These dates are known as the *solstices* because in connection with them are a few days in each instance when there is only slight change in the daily period of sunlight. June marks the period of the summer solstice in the Northern Hemisphere and of the winter solstice in the Southern Hemisphere. December, on the other hand, is the period of the winter solstice in the north and of the summer solstice in the south. Twice yearly, about March 21 and September 22, the sun stands vertically over the equator, midway between the two tropics. We speak of these dates as the *equinoxes,* because days and nights are then each of twelve hours duration all over the earth. Between March 21 and September 22 the sun rises north of east and sets north of west, whereas from September 23 to March 21 the sun rises south of east and sets south of west. Thus it is clear that only in the area between the two tropics can the sun appear in the zenith. At the equator the sun can never be farther from the zenith at noon than 23½°, while toward the tropics this figure gradually increases to 47°.

In higher latitudes the differences in the angles of the sun's rays are much more significant. At 50°N., for example, the maximum angle above the horizon in June is 63½°, and the minimum angle in December, 16½°. By referring to pages 63 and 65 it will be clear that the effects of these different angles in the middle and higher latitudes are much greater than in the region between the Tropic of Cancer and the Tropic of Capricorn.

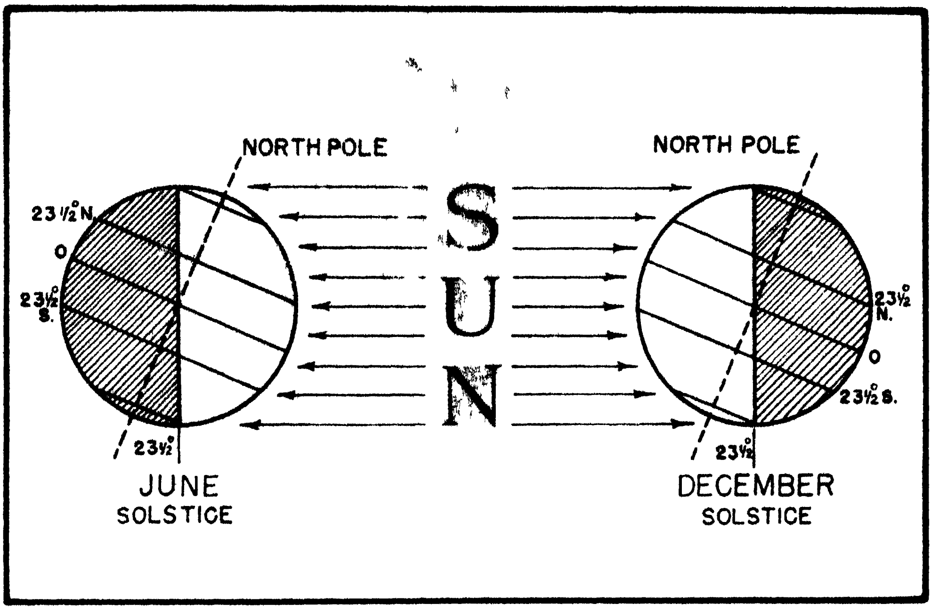
The effects of rotation upon heat distribution. The rotation of the earth on its axis once in 24 hours gives within that period heat and light as well as darkness to most parts of its surface. The sun appears to rise in the east, to travel across the sky, and then to set in the west. Actually, however, the earth is turning in the opposite direction, from west to east. Deception in such matters is often experienced. Who has not had the sensation of moving while seated in a Pullman, only to discover a little later that the train on the next track was slowly pulling out of the station?

The change from day to night causes minor fluctuations in temperature. During the day insolation ordinarily raises the temperature about us. At night, part of the heat accumulated during the daytime is given off, radiated into space, and temperatures drop. These daily fluctuations are of considerable economic importance. They prevent excessive heating. In many parts of the world the nights give some respite from the heat of the daytime. In the spring, the daytime temperatures may be favorable for plant growth, but the low temperatures of the early morning often bring with them the danger of frosts.

If the earth rotated on an axis standing vertically to the plane of its orbit, days and nights would always be of equal length. Since the axis is inclined at an angle of 23½°, the respective lengths of day and night vary in the course of the year. In the Northern Hemisphere in June the days are longer than the nights; in December, the reverse holds true (Illus. below).

Although near the equator the difference between the length of day and night is relatively slight, toward the poles it becomes steadily greater until, beyond the polar circles, there are both a polar day and a polar night of increasing duration.

Thus, differences in the length of day and night accentuate temperature differences due to the seasons. With increasing latitude, summer insolation lasts a longer, and winter insolation a shorter, period.



Angles at which the sun's rays strike the surface on June 22 and December 22. Note the Tropics of Cancer and Capricorn, and the Polar Circles. Also note day and night.

Seasonal changes in heat distribution. Near the equator and approximately as far north and south as the Tropics of Cancer and Capricorn respectively, the noonday sun is always high in the sky. The sun's rays strike at a fairly high angle and lose little to the atmosphere. Besides, the days are never short. Consequently, this part of the earth's surface is relatively warm all year. The seasons are characterized not so much by differences in temperature as by fluctuations in the rainfall during the course of the year. Vegetative growth never entirely ceases, although in some sections of this zone the occurrence of an annual dry season may cause most of the trees and shrubs to shed their leaves, thus creating a landscape similar in some respects to that of the northern winter.

In the middle latitudes, there is a pronounced temperature contrast between the period during which the noon sun stands high and that during which it stands low in the sky. In these regions we have a true summer and a true winter. The summer is the growing season, the winter is the season during which the entire vegetation is inactive for lack of sufficient heat. Near the poles, the temperatures are so low even in the warmer half of the year that vegetation growth is impossible. These are the areas of perpetual ice and snow.

If the axis were not inclined. Were the earth's axis not inclined, there would be no seasons and the world would be markedly different from the one we inhabit. The warm belt would be a narrow band of excessive heat gradually merging into cooler areas to the north and south. There would be no regions with alternating summers and winters. The frozen wastes about the poles would extend farther equatorward than they do now. Days and nights would be of equal length everywhere. At any given place the daily insolation would remain unchanged throughout the year. It is difficult to visualize such a world, one of unending climatic monotony in contrast to the stimulating diversity which is our present condition.

Elements of Weather and Climate

The elements of the weather which are studied separately and in combination for purposes of weather forecasting are: (1) temperature, (2) barometric pressure, (3) wind direction and wind velocity, (4) humidity, (5) cloudiness and sunshine, (6) precipitation, and there are a few others.

For the description, classification, and explanation of climatic conditions, as has been mentioned before, we must depend largely upon meteorological data gathered primarily for purposes of weather forecasting. (Illus. p. 67.) Instead of using observations for one day or hour, average values are calculated on the basis of observations which may run over many years, ten, twenty, and preferably more than twenty-five years. It is clear that a tremendous amount of calculating is involved for each station used.[1]

The elements of greatest interest for climatic study are somewhat different from those of prime importance for the study of the weather. In many cases also, the phases of the elements concerned are different.

For example, in the study of climate, barometric pressure is of subordinate importance, while in meteorology, it is of prime importance. One reason is that men, plants, or animals do not seem to be greatly affected by ordinary differences in pressure. On the other hand, precipitation looms large as a climatic element, because of its great importance for agriculture and other activities of man. While temperatures are important to both, temperatures of the upper atmosphere probably are not quite so important in climatology as they are in weather forecasting. Similarly, in so far as humidity is concerned, vapor pressure and specific humidity are important to the meteorologist, whereas relative humidity and evaporation are of great direct interest to the student of climatology.

Temperature, air pressure and winds, and precipitation are discussed at this point because they are considered to be the most important elements.

1. Temperature. Temperature is the term used to express the intensity or degree of heat. It is measured by means of a thermometer or thermograph. Energy is radiated into space by the sun, and although the earth intercepts but a very small fraction of the total, this fraction is the source of practically all the heat energy available upon the earth. Of the radiation that reaches the surface of the earth, part is reflected back and part is absorbed by the surface. The amount reflected usually is small—less than 10 per cent—but may be high in the case of snow-covered surfaces, such as the Antarctic continent or the frozen North Polar Sea. Part of the radiant energy absorbed by the surface is changed into heat, which is transferred by radiation and conduction to the air immediately above. Thus the atmosphere is heated primarily from below.

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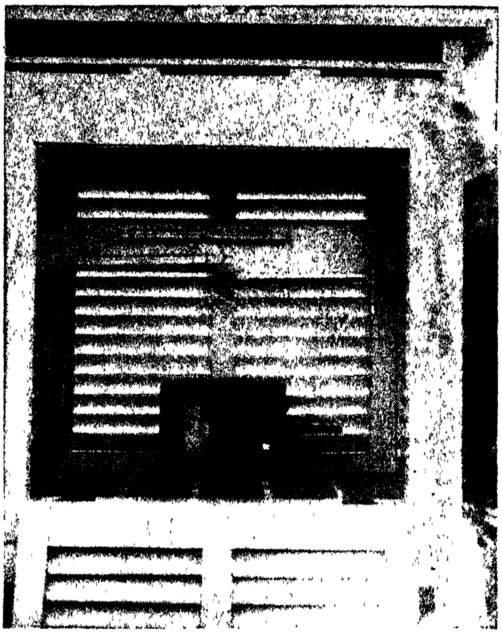
[1] Fortunately, modern punch-card methods have proved a great aid in the use of available basic statistics.



Courtesy U. S Weather Bureau.

Instrument shelter at a U S. Weather Station. The black box contains a thermograph, or self-registering thermometer. Other thermometers can be seen above. To the left is a sling psychrometer for the determination of relative humidity.

The temperature of the air always lags somewhat behind that of the earth. Neither does the air heat up as much during the day or cool as much during the night as does the earth. Maximum air temperatures do not occur at noon, but in the afternoon, while minimum temperatures ordinarily occur in the early morning hours, rather than around midnight. What is true in the course of a day is also true in the course ot a year. The lowest winter temperatures occur after the winter solstice, in January, or even February, and the highest summer temperatures usually occur not in June, but in July and August.

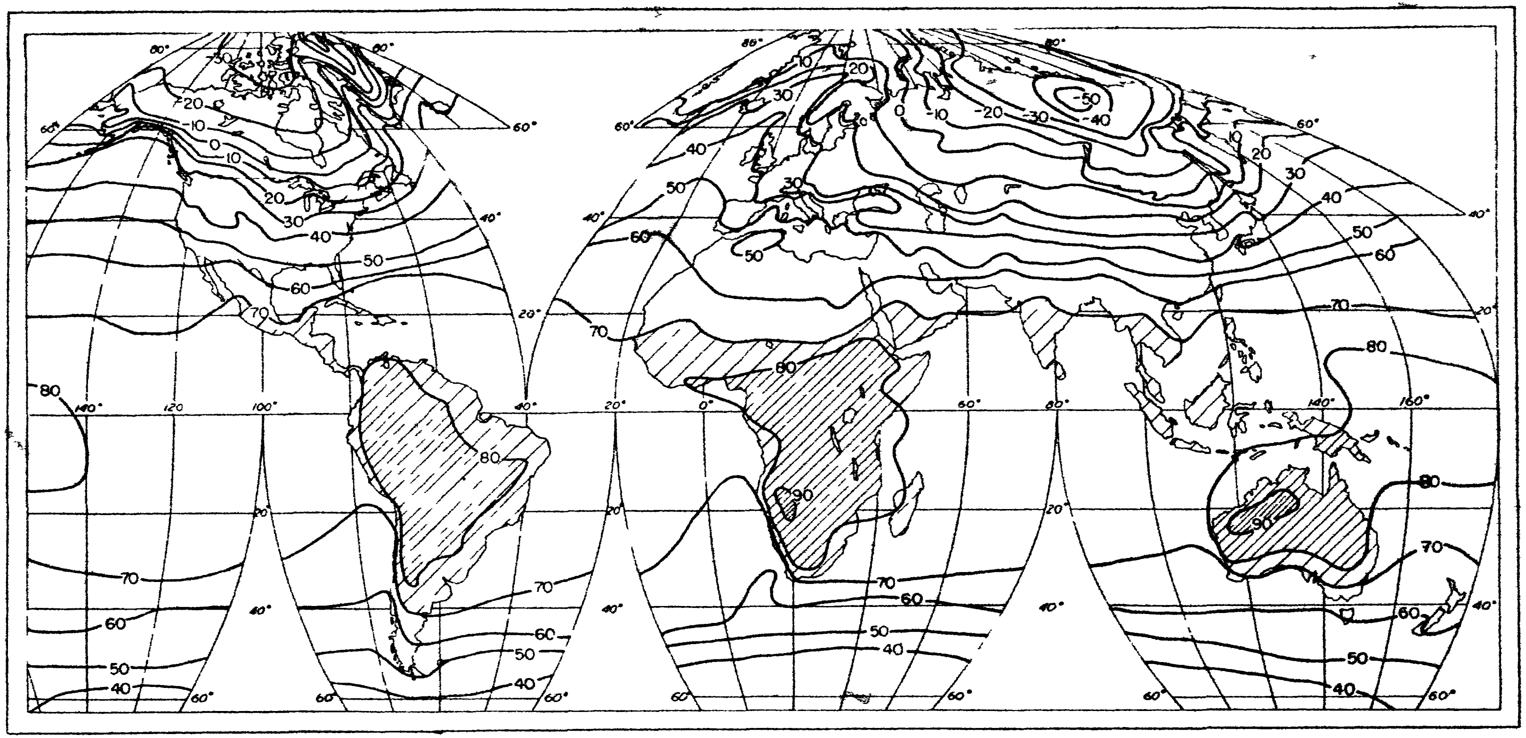
The difference between the highest and the lowest temperature during twenty-four hours is called the daily or diurnal range, while the difference between the average temperature of the warmest and the coldest month is called the seasonal range. The amount of seasonal range is an important climatic criterion.

Distribution of heat on the earth without circulation. If the atmosphere were completely at rest, and if, besides, land masses and water bodies were equally distributed, temperatures would be as given below for each one of the latitudes listed.

Latitude	0	10	20	30	40	50	60	70	80	90
Temperature, degrees F. ...	91	89	83	72	57	37	12	−11	−26	−31
Actually observed temperatures ..	79	80	78	69	57	42	30	14	2	?

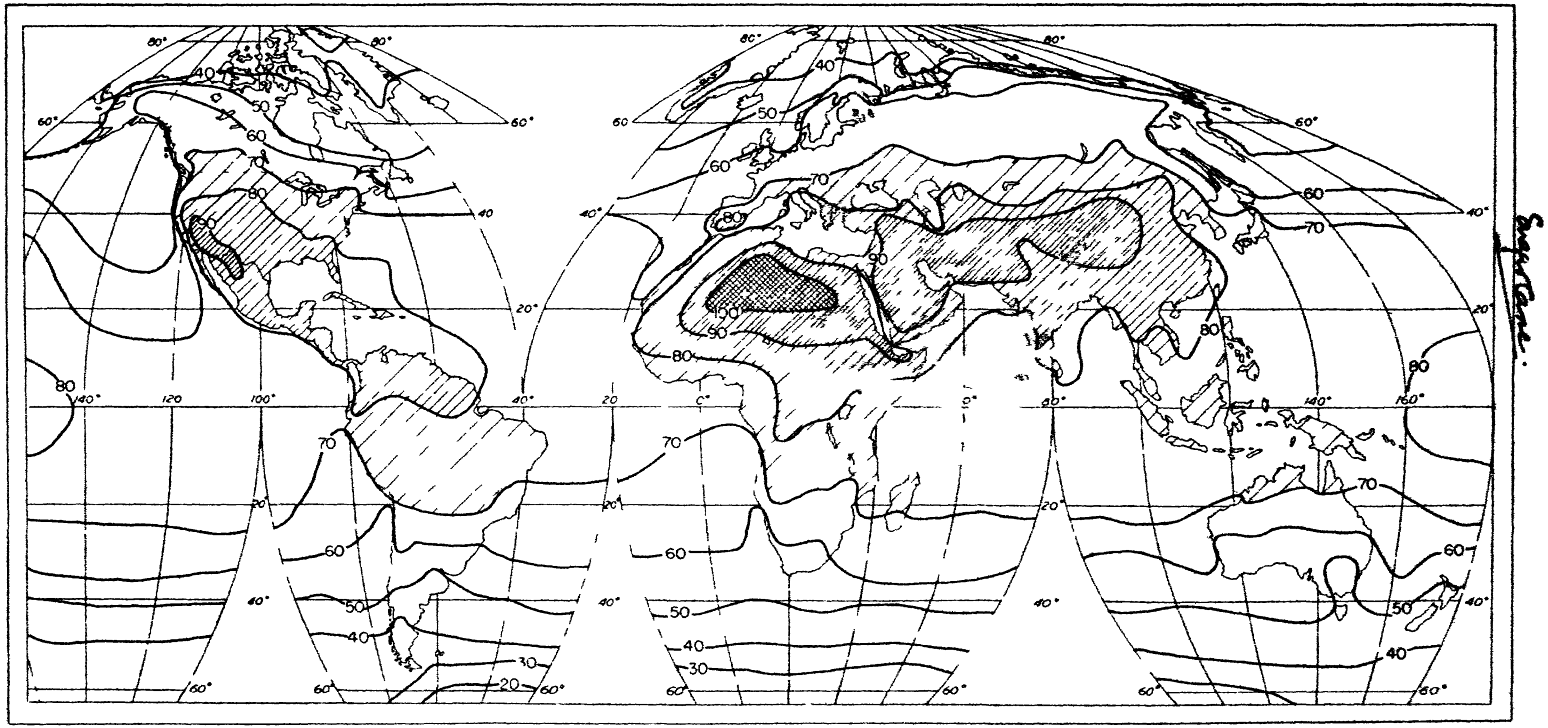
As can be seen from the observed averages, actual conditions correspond closely only in about latitude 40; while from here to the equator observed values are lower, in the higher latitudes they considerably exceed the theoretical values. This is due to the facts that the atmosphere is not at rest—that is, there exists a general circulation by which heat is transferred—and that land and water masses are not evenly distributed.

The effects of unequal heating of land and water. The effects of the sun's rays on land and water are not the same. Equal insolation results in less rise in temperature of water than of land. This is due to three major factors: (1) the relatively high specific heat of water—that is, more calories of



Isothermal lines for January Degrees Fahrenheit Cross-hatched sections are land areas with average January temperatures of 70°–80°F., 80°–90°F., and over 90°F

Sugarcane.



Isothermal lines for July Degrees Fahrenheit Cross-hatched sections are land areas with average July temperatures of 70°–80°F, 80°–90°F, and over 90°F heat are necessary to raise the temperature of water than of land 1°; (2) the transparency of water allows the sun's rays to penetrate to a much greater depth than on land, and thus the intensity of heating at the surface is less; and (3) the mobility of water permits transference of heat to colder layers or places by means of waves, currents, and settling.

As a result of all these factors, water bodies remain at much steadier temperatures than land areas. During the summer, in the middle latitudes the land is much warmer than the ocean; in the winter, it is much colder. We are all familiar with this phenomenon. In June the air in the middle latitudes may feel balmy, but the water of lake, or river, or "the old swimming hole" may feel disagreeably cold; while in the fall, swimming may be pleasant as long as one remains well submerged. This difference is of great climatological importance, especially in winter. Extensive water bodies moderate the temperatures of near-by land masses when winds are blowing toward the land.

OCEAN CURRENTS. Other modifications in the general distribution of heat over the world are caused by warm and cool ocean currents. Such currents, moving toward cooler or warmer areas, will affect the masses which move over them, and these, in turn, may affect adjacent land masses. The relatively warmer water of the Gulf Stream Drift, for example, coupled with winds from the ocean, brings ice-free winter conditions to beyond the northern tip of Norway, whereas in the same latitudes in North America, the surface of the sea is frozen.

INFLUENCE OF ALTITUDE. Differences in altitude also lead to differences in temperature. At the higher altitudes, insolation results in less heating because of the greater loss of heat by radiation through the rarefied atmosphere. Thus, mountain and plateau regions always have lower average temperatures than have neighboring lowland areas.

WORLD DISTRIBUTION OF HEAT. Distribution of temperatures is shown most graphically on maps, not by means of individual temperature figures, but by means of lines connecting points with equal temperatures. Such lines are called *isotherms*. An isothermal map of the world based upon actual average annual temperatures clearly shows the disturbing effects of the factors mentioned above. The isotherms do not follow the parallels around the globe, as one might expect; they bend northward and southward (Illus. pp. 68 and 69). The irregular courses of the isotherms are due (1) to the unequal distribution of land and water and the resulting unequal heating, (2) to the transference of warm and cold air by prevailing winds, (3) to the transference of equatorial heat poleward and of polar cold equatorward by means of ocean currents, and (4) to the occurrence of highland areas.

TEMPERATURE AS A CLIMATIC ELEMENT. From a climatic point of view, average monthly and average annual temperatures are most important. Usually averages for January and July are taken as most characteristic. For certain purposes, average maximum and minimum temperatures, or even absolute maxima and minima, may be needed. As has already been stated, the seasonal range of temperature is important climatologically, as it indicates the degree to which the climate is influenced by land masses or water bodies, in other words, the degree of continentality or oceanity. Data on the average occurrence of the first and the last killing frost are useful in connection with crop production, as are also data on the length of the frost-free season.

The changeable temperatures of the middle latitudes furnish an inexhaustible subject of conversation because of their direct relationship to our pursuits and pleasures. But more than that is involved. Changeableness of temperature, and of weather conditions in general, seems to have an energizing influence. The enervating effect of the monotonously warm and humid weather of the rainy tropics is well known. There, hustling white men from cooler climes gradually and almost inevitably become slow-moving, since in the long run the climate is not conducive to such activity as is possible in the middle latitudes.

In the high latitudes, conditions of a different kind are encountered. There, Nature is so harsh that agriculture and industry must leave the field to hunting and fishing.

2. ***Air Pressure and Winds.*** The atmospheric air, obeying the laws of gases, exerts pressure in all directions, the amount of pressure varying with the density of the air. At sea level, where the air is weighted down by all the air above it, density is greatest, and the pressure amounts on the average to 14.7 pounds per square inch. At greater altitudes, where the air is less weighted down and therefore not so dense, the pressure is less. Air pressure is measured by means of the barometer and the barograph. At sea level, the normal atmospheric pressure is indicated by a barometric reading of 29.92 inches, or 760 millimeters; that is, the atmospheric pressure is sufficient to balance a column of mercury about 30 inches high. Another unit of measure is the millibar (m6). A pressure of 1013.2 m6 is the normal. With increase in altitude, the height of the column of mercury that the air pressure can sustain decreases in the beginning at the rate of about one-eighth of an inch per 100 feet. The rate decreases at higher altitudes. The accompanying table illustrates more accurately the rate of change.

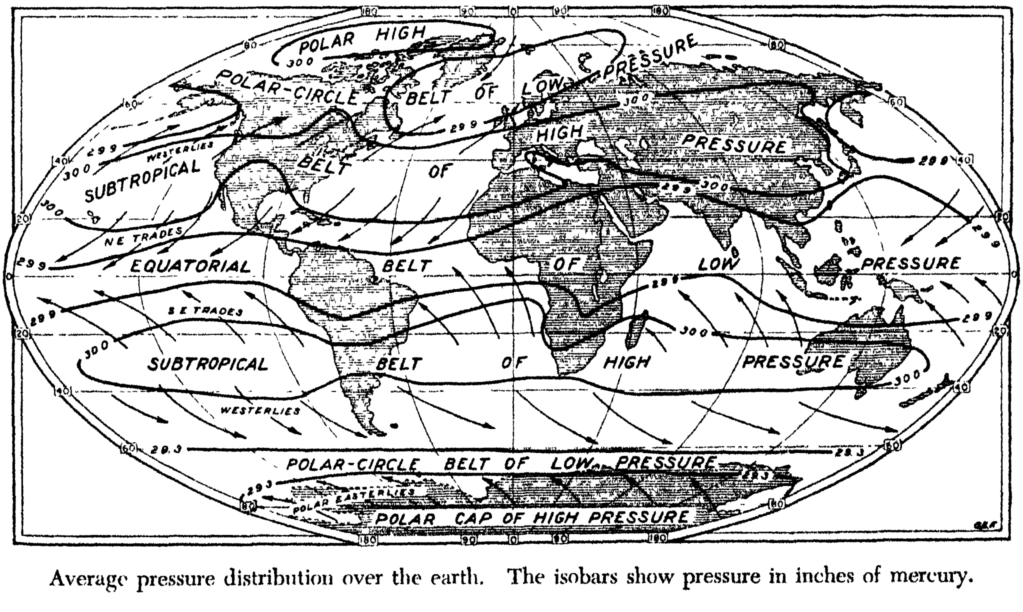
Relation of Air Pressure to Altitude

Altitude	*Barometer*
−73 feet	30 inches
863 feet	29 inches
1,824 feet	28 inches
2,814 feet	27 inches
3,824 feet	26 inches
4,886 feet	25 inches
5,974 feet	24 inches

Barometric pressure is important especially for purposes of weather forecasting. For this, not only pressures at the surface, but also pressures at higher altitudes in the free atmosphere are used.

Pressure beyond the normals mentioned above are called "high" pressures; those below, "low" pressures. Distribution of atmospheric pressure is shown on maps most adequately by means of lines of equal pressure known as *isobars.* Such isobars appear on all modern weather maps and show clearly the areas of high and low pressure, as well as the transitional regions (Illus. below).

Air tends to move from higher pressure to lower pressure, and generally speaking, the


POLAR HIGH
POLAR-CIRCLE BELT OF LOW PRESSURE
HIGH PRESSURE
SUBTROPICAL BELT OF HIGH PRESSURE
WESTERLIES
NE TRADES
EQUATORIAL BELT OF LOW PRESSURE
SE TRADES
SUBTROPICAL BELT OF HIGH PRESSURE
WESTERLIES
POLAR-CIRCLE BELT OF LOW PRESSURE
POLAR EASTERLIES
POLAR CAP OF HIGH PRESSURE
30.0
29.9
29.3
180
90
0
90
180
60
40
20
0
20
40
60

Average pressure distribution over the earth. The isobars show pressure in inches of mercury.

greater the difference in pressure per unit of distance (the pressure gradient), the faster the air will move. Owing to the rotation of the earth, centrifugal force, and friction the direction of air movement is changed so that movement is not directly from high to low, but follows a curving path.

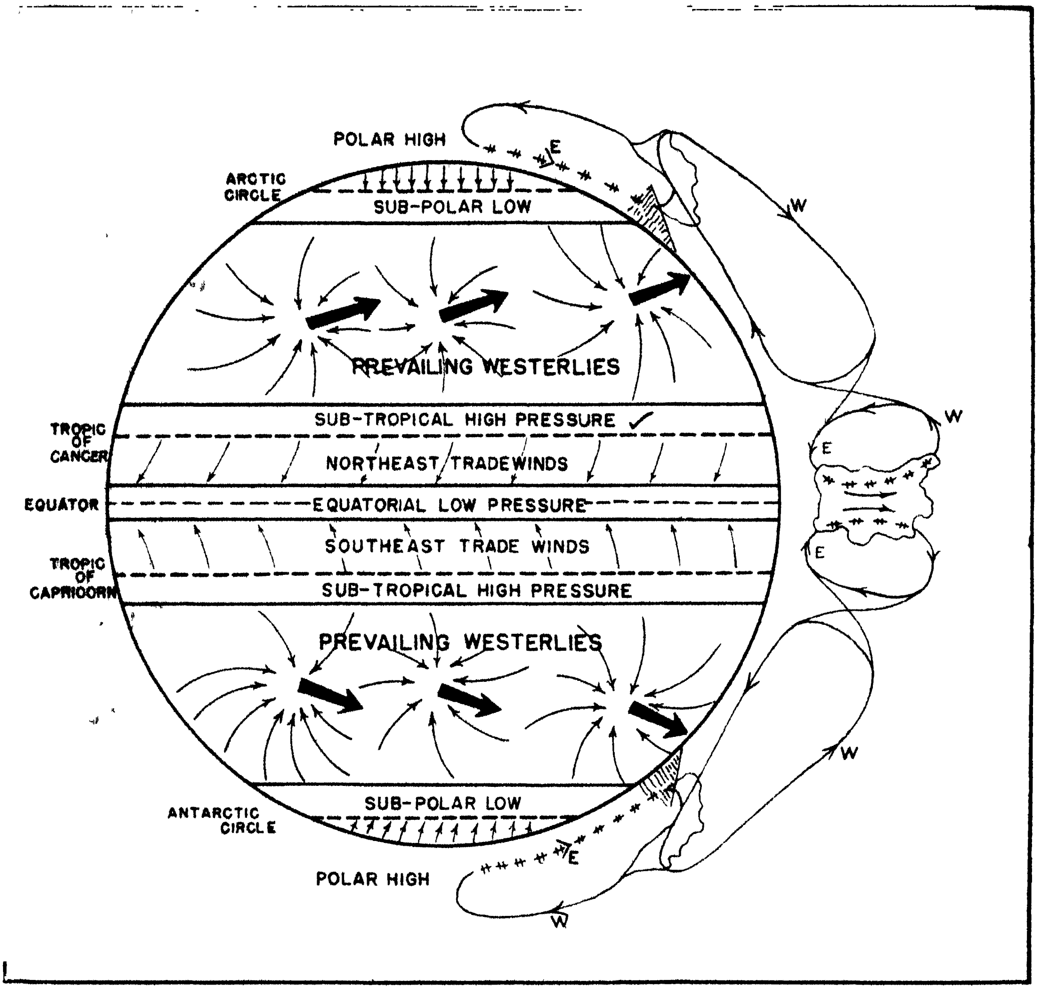


Diagram of the wind belts of the world. The belts of the prevailing westerlies are represented schematically by moving lows and highs, the heavy arrow indicating only a predominant trend of direction of movement. Note the diagram—highly exaggerated and schematic—of air circulation on the right margin.

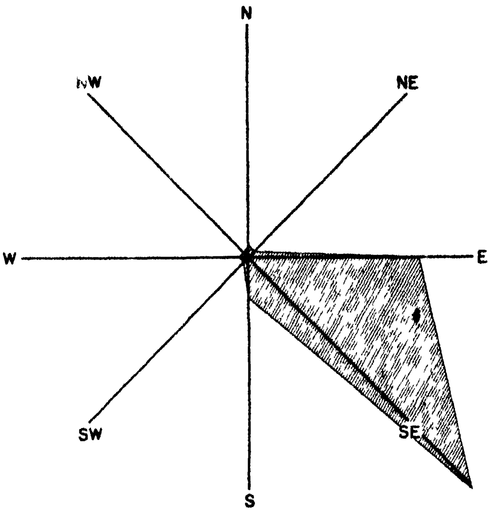
From a climatological point of view barometric pressure in itself is not of major importance, as its effect upon living organisms is not readily appreciated. However, it is of importance for the study of causal relationships in climatology.

Vertical movements in the air are ordinarily spoken of as *currents*. The velocity of the wind is expressed in miles per hour and is measured by a device known as the *anemometer*. When air is at rest relative to surrounding objects, we are scarcely aware of its presence; but when it is in motion, as wind, we readily recognize it because of the pressure or force which it exerts. Atmosphere as a whole would be relatively calm if it were not for the unequal distribution of insolation over the earth's surface. This unequal heating gives rise to differences in pressure, which result in the phenomenon of wind. The winds are named as to the direction from which they blow; thus, if air moves from the north toward the south, it is spoken of as a north wind. The direction from which the winds blow with greatest frequency at a given place is called *the direction of prevailing winds.* In ordinary accounts of wind velocity we are likely to find it referred to in approximate terms, such as calms; light, moderate, or strong winds; and gales or storms. Wind strength can be described more accurately by means of the Beaufort scale, which has 12 numerical divisions, ranging from 1, calm (less than 1 mile per hour) to 12, hurricane (over 75 miles per hour). Climatologically wind strength is important as it may have strong, direct effects on crops and vegetation and may greatly influence rates of evaporation.

Wind direction is also an important climatological criterion. In some areas winds blow steadily from one prevailing direction during most of the year, as in some parts of the tropics. In still other areas, prevailing wind directions during summer and winter may be roughly opposite, as in the monsoon countries. In the middle latitudes, the so-called areas of the "prevailing westerly winds," the most important characteristic of the climate in so far as wind is concerned is really the fact that during practically all of the year the wind may come from any of the points of the compass.

THE GENERAL CIRCULATION. The average general distribution of air movement in the atmosphere is referred to as the *general circulation.* On the basis of the average distribution of winds, the earth may be divided into a few large zones or *wind belts.* This system of wind belts is represented in highly schematic form on page 72. It must, of course, be understood that the lines between the belts are neither sharp, nor straight, nor stable.

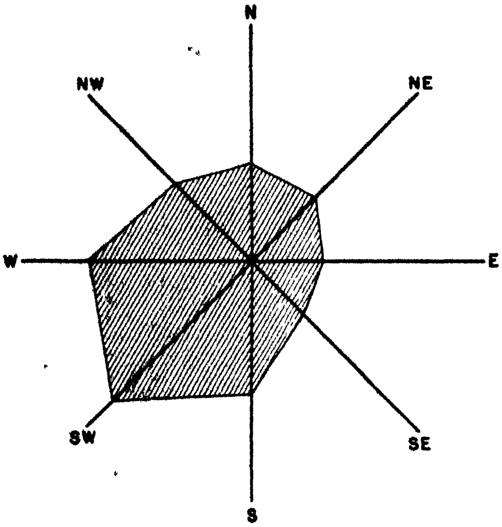
Since the annual insolation is greatest near the equator, a belt of slightly below average pressure (29.9 to 29.8 inches) encircles the earth there; this belt is known as the *equatorial belt of low pressure,* or the *doldrums.* The term doldrums is applied most generally to the equatorial calms over the oceans, but lack of any better term seems to make it applicable to the corresponding belt of calms and variable winds over the lands as well. The belt varies in width, and in places may even temporarily be absent. Part of the belt lies slightly north of the equator, in Southwestern Asia. Due to the persistent heating, ascending air movements are prevalent. Thus, the doldrums are characterized by light, baffling breezes, interspersed with prolonged calms.



Wind rose characteristic of the trade winds. Fernando Noroñha Island, northeast of Recife, Brazil

On the poleward sides of the tropics lie two belts where the atmospheric pressure remains relatively high all year through (from 30.0 to over 30.1 inches). These are the so-called *subtropical highs* (horse latitudes), which are most persistent over the oceans. Two of these high-pressure areas are permanent in the Northern Hemisphere: one in the North Atlantic, approximately at the latitude of the Azores, the other in the North Pacific. The Azores High and the North Pacific High are strongest in summer and weakest in winter. The other three permanent subtropical highs are located respectively over the southeast Pacific, the southern Indian Ocean, and the South Atlantic. In these regions, as in the doldrums, calms are frequent (Illus. p. 71).

Along the surface—that is, to altitudes from 10,000 to 30,000 feet—winds blow from the subtropical high-pressure belts toward the equatorial belt of low pressure. These winds, blowing from the northeast in the Northern Hemisphere and from the southeast in the southern, are called *trade winds*. Their velocities vary from moderate to brisk, and their direction, particularly over the oceans, may remain unchanged for weeks at a time. A typical wind rose[1] for a trade-wind area is given on page 73, which shows, for an island in the southeast trade winds, that wind directions are almost exclusively from southeast to east. In the Dominican Republic, located in the northeast trades, wind directions may be largely from the northeast or east on the southern coast, even from the southeast.



Wind rose characteristic of the westerlies. Stornoway, Hebrides Island, off the coast of Scotland.

At higher altitudes there is a movement of air from the Equatorial Low Pressure Belt to the horse latitudes. These are the so-called *antitrades*, which have a strong westerly component (Illus. p. 72). Sometimes, when the Equatorial Low Pressure Belt is very narrow, weak, and even temporarily absent, the trade-wind systems from both hemispheres may meet in the equatorial region. A surface of discontinuity forms in that case, along which strong rain squalls may occur. This is called the *equatorial*, or *intertropical front*.

Poleward, beyond the subtropical highs, lie the belts of the "prevailing westerlies." They are best developed in the Southern Hemisphere, where air movements have free play because of the absence of large land masses. In the northern hemisphere, the presence of the North American and Eurasian continents causes many modifications in airflow.

The surface winds in these belts, especially in the northern middle latitudes, are highly variable in direction and in velocity, and airflow is characterized by the existence of irregular, and often vast, whirl-like movements toward centers of low pressure and away from centers of high pressure.

The name "prevailing westerlies" for these belts is somewhat misleading, particularly if it is shortened, as is often done, to just "westerlies." As may be seen on the left, a wind rose for an island off the coast of Great Britain, winds from the southwesterly quadrant predominate in the course of a year (in North America winds from the northwesterly quadrant would be likely to prevail), but the most significant characteristic of these belts is that at any time of the year winds may come from any point of the compass.

The great whirls of low and high pressure are called *cyclones* and *anticyclones*, respectively. Their height varies between two and six miles, and they have diameters of as much as 500 to 1,000 miles. They move generally from west to east, not in straight paths, but in curving paths, deviating from a true west-east direction. The cyclones, or "lows," are most pronounced in winter, and at that time they are likely to move most rapidly and go farthest southward. Occasionally a "low" is observed that makes the entire circuit, from Alaska or the North Pacific, through Canada and the United States, over the North Atlantic, through Europe and northern Asia, and back again to Alaska. Usually, however, they weaken and disappear somewhere along the route. The "highs" are more slow-moving, and sometimes they even seem to be stationary for a while, thus impeding the freer movements of the lows. In the summertime, the lows and highs are neither so pronounced as in the winter, nor do they move so rapidly. Their paths lie, on the average, farther north in this season.

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[1] A "wind rose" is a diagrammatic representation of average wind directions in one place. The length of the arms shows the relative frequency of each main wind direction.

The belts of the "prevailing westerlies," or the "cyclonic storm belts," are really areas of conflict between relatively warm masses of air emanating from the subtropical highs, and masses of cold air, which roll forward from the next belt to the north. Beyond 65° to 70° north or south there exist most of the year large masses of cold, polar air, which tend to move out of this belt as northeasterly winds in the Northern Hemisphere and southeasterly winds in the Southern Hemisphere. The masses of cold air, being heavier, tend to move under masses of warm, subtropical air coming from the south. Where they meet, a surface of discontinuity is formed, a well-marked and distinct surface of separation between the two air masses, which are distinct in temperature, humidity, and other characteristics. This surface is the *polar front.* At the surface, cold air replaces warmer air. The polar front usually is best developed in, or in association with, pronounced cyclones. A rapid advance of the polar front in the winter season may bring low temperatures far toward the subtropics.

There is a pronounced belt of low pressure in the Southern Hemisphere between latitudes 60 and 70. In the Northern Hemisphere there are two areas of average below normal pressure near the Polar Circle, one in the neighborhood of the Aleutian Islands, the other in the vicinity of Iceland. These lows may be considered as incidents within the belts of the prevailing westerlies.

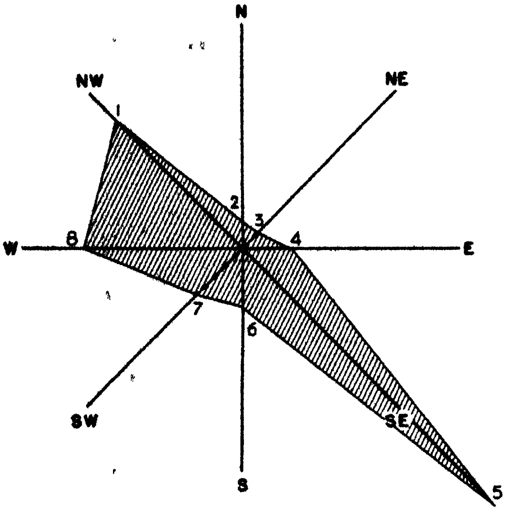
While pressure over the north polar area tends to be above normal, there is no permanent high-pressure "cap" over the Polar Sea, but rather a number of individual high-pressure areas over adjacent far-northern land masses. In Antarctica a high-pressure "cap" seems to be permanent.

The pressure and wind belts are most clearly developed over the oceans, and it is therefore easiest to estimate the part of the oceans over which each of the wind systems discussed above prevails. The doldrums exist over 9 per cent of the ocean surface, the trade winds over 31 per cent, the subtropical high pressures over 20 per cent, the prevailing westerlies over 24 per cent, and the polar systems over 10 per cent. This leaves 9 per cent over which monsoon currents predominate.

Climatic importance of the general circulation. There are many relationships between climate and the general circulation pattern. For example, there are pronounced differences between the Equatorial Low Pressure area and the adjacent trade-wind belts. Within the trade-wind belts it makes a great difference whether the air masses strike over level land or sea, or whether they encounter mountain regions. In the belts of the prevailing westerlies, owing to prevailing wind direction, there are profound differences between east coasts, which have predominance of land winds, and west coasts, which have predominance of sea winds.

As the wind belts tend to move northward and southward with the sun (there is a certain time lag, however), further climatic complications are introduced. For example, in subtropical latitudes—those between the tropics and the middle latitudes—during the summer season the subtropical highs or trade winds may predominate, while during the winter the prevailing westerlies may control the circulation.

Seasonal changes in wind directions. Warm air is less dense than cold air; hence, areas of warm air are often characterized by lower pressures than are areas of cool air. In the middle latitudes, particularly in the northern hemisphere where land masses are large, the interiors of the continents in summer are considerably warmer than the neighboring oceans. In winter they are considerably colder. Over the continents the air becomes heated in the summertime, strong convectional currents develop, and the air flows outward to the oceans at higher levels. Thus, average below-normal pressure is created in the interior, and air masses tend to flow into the continent along the surface from the cooler areas with higher pressures over the adjacent seas. During the period of intense heating in summer, these winds from ocean to land are well developed; as autumn advances, the movement slows down until a relative equilibrium is attained. Then as winter sets in and the air above the land is chilled more rapidly than the air above the ocean, the processes are reversed. The air pressure over the continental interiors becomes greater than over the oceans, and thus surface winds tend to blow outward from the continental high-pressure areas toward the low-pressure areas over and adjacent to the oceans. These seasonal wind shifts are known as *monsoons* (Illus. above). They are best developed in eastern Asia (Illus. p. 77), but are also important in the Gulf area of North America and the adjacent plains.



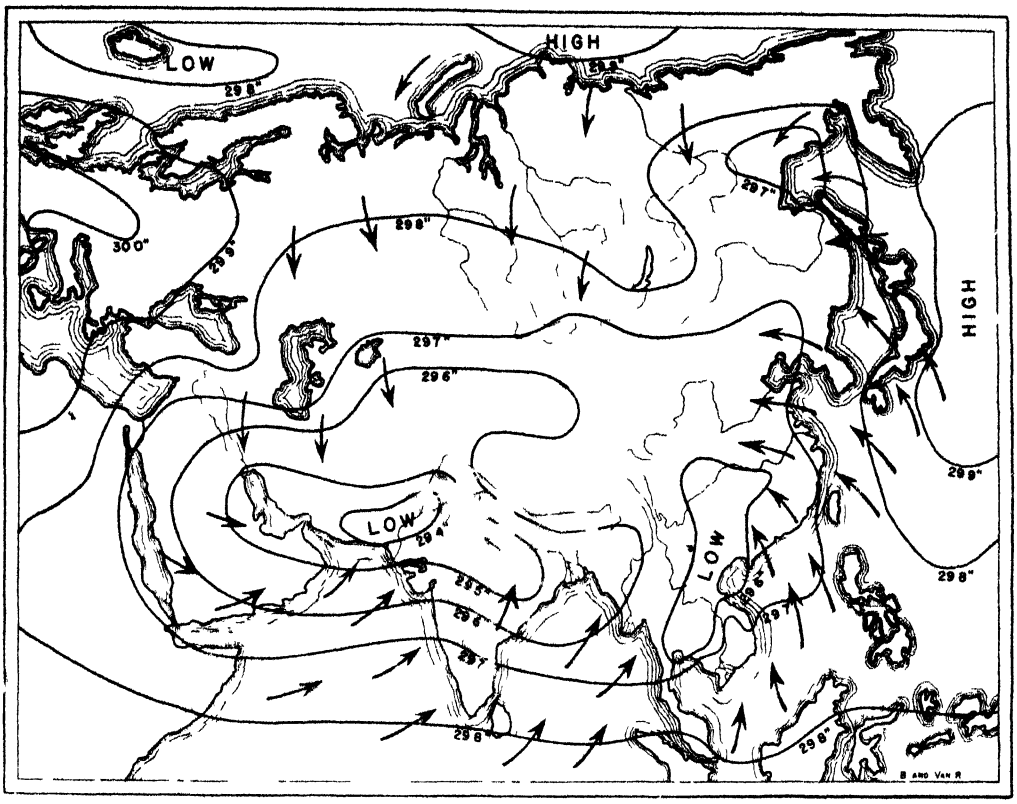
Wind rose characteristic of the monsoon type of climate. Discovery—East Bank, Southeast of Billiton Island, between Sumatra and Borneo.

Humidity. Humidity is the moisture associated with the air in the form of an invisible gas known as *water vapor.* It is one of the principal elements of climate. *Absolute humidity* is the quantity of water vapor present in the air, expressed in the number of grams per cubic centimeter, or the number of grains per cubic foot. *Specific humidity* is the relationship between the weight of the water vapor in a unit weight of air and the weight of that air. For climatological purposes relative humidity is more important than either of the above. *Relative humidity* is the ratio between the actual quantity of water vapor in a unit volume of air and the maximum amount that could be held in that space at the same temperature without condensation.

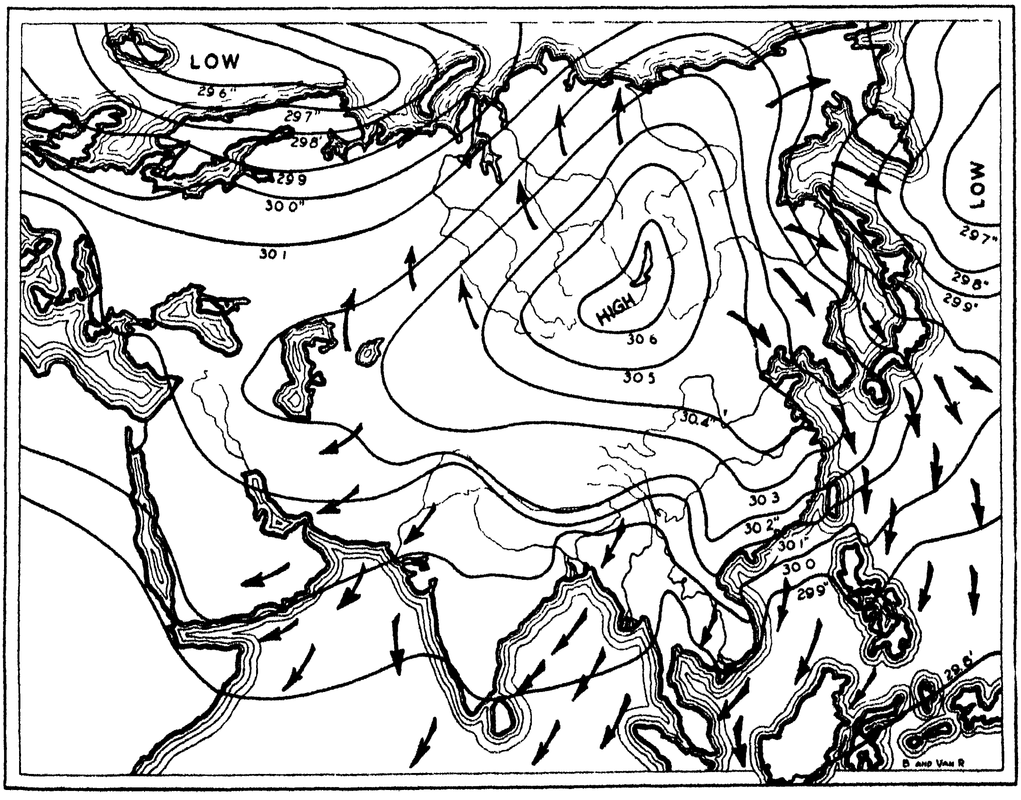
The point of saturation, known as the *dewpoint,* is reached when any volume of air contains as much water vapor as can exist there without condensation.

Humidity is measured by an instrument known as a *psychrometer* or a *hygrometer.* Records of humidity are usually kept as relative humidity in terms of percentages, as 40, 70, 90, and so on, in each case the saturation point being 100. The capacity for containing water vapor increases with temperature. For this reason the relative humidity is often greater in cold weather than in warm weather, even though the absolute humidity, or actual weight of water vapor in a given volume of the air, may be less. Temperature and relative humidity have a close relationship to evaporation. The higher the temperature and the lower the relative humidity, the greater the evaporation. On dry, sunshiny summer days roads and fields dry up quickly after a rain, while in early spring or winter even small rains give rise to a muddy condition which may last a long time.

Relative humidity is a fairly important climatic criterion, because of its relationship to evaporation, and also because high relative humidity is sensed easily by the human



(A) Atmospheric pressure and winds in Asia in July



body. "Muggy" summer days may cause a greater sensation of heat than the thermometer reading would indicate, while "raw" winter days may feel much colder. Unfortunately, climatic data on relative humidity are much more scarce than those on many of the other climatic elements.

4. ***Precipitation.*** It has already been pointed out that dewpoint is the temperature at which air is saturated with moisture. Since the capacity of any given volume of air for retaining water vapor is largely dependent upon its temperature, when warm air is cooled, its capacity for holding its moisture content is reduced. When dewpoint is reached, the surplus begins to condense; that is, part of the invisible water vapor changes into visible water or ice. In the atmosphere the surplus takes on the form of clouds, fog, rain, snow, hail, dew, or frost, depending upon the conditions under which condensation takes place.

Clouds consist of fine droplets of water or ice crystals. The droplets tend to fall to earth but are often kept floating by upward or transverse air currents. When these droplets grow in size, rain may result.

The amount of rainfall is measured in inches or millimeters. The rain water may be caught in any open, vertical-walled vessel and its depth measured directly. The standard rain gauge, however, is a cylinder which drains through a funnel into a lower-placed cylinder with a cross-section area one-tenth as large as the upper one. Thus, the lower cylinder registers one inch for each one-tenth inch of rainfall. In this manner, readings of greater accuracy are obtainable than through direct readings in the larger open vessel. Precipitation is best represented on maps by means of lines of equal precipitation, called *isohyets.*

The cooling of the air, necessary to cause condensation of water vapor, may be produced in three ways: (1) adiabatic cooling —that is, cooling by expansion as the moist air rises or is forced to rise; (2) mixing of warm and cold air masses; and (3) cooling by contact with cold surfaces. Of these three, adiabatic cooling is responsible for most of the precipitation of the world. It may be brought about (1) by convectional currents which may give rise to *convectional rain;* (2) by winds ascending mountain slopes and thus producing *orographic rain;* (3) by cold air masses wedging underneath masses of moist, warm air and forcing them upward, or by warm, moist air being forced to over-ride masses of cooler, heavier air, in either case producing *cyclonic rain.* The heavy rains characteristic of the equatorial belt and the summer thunderstorm showers of the middle latitudes are usually of the convectional type. Mixing of masses of warm and cold air may give rise to the formation of light clouds, but it usually results in little precipitation. Contact with cold surfaces may cause condensation, as dew, frost, or fog, but rarely produces rain.

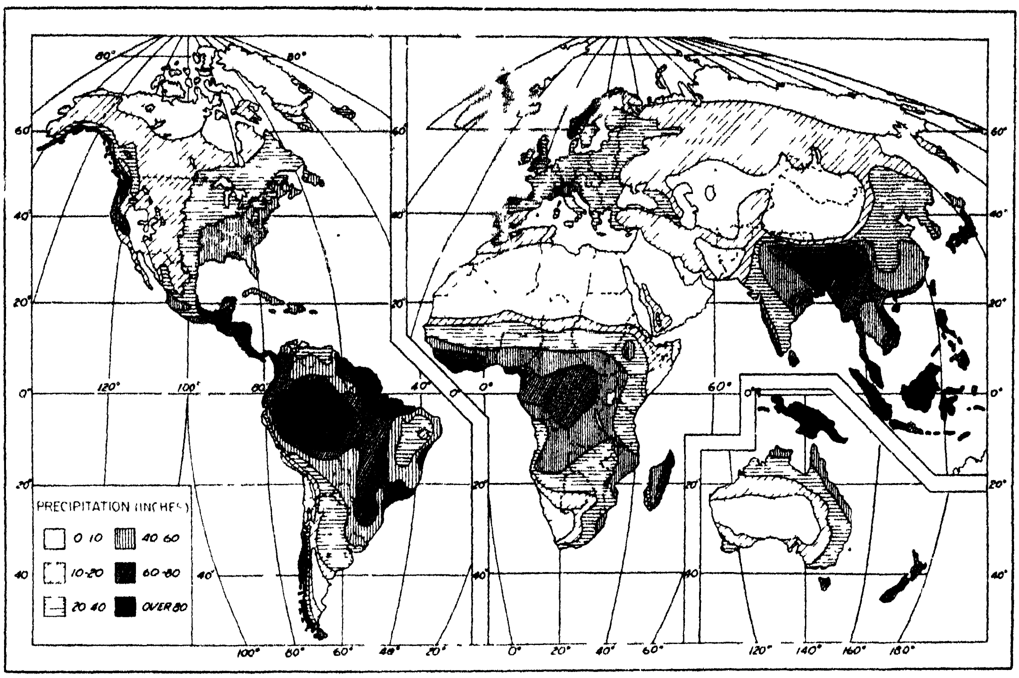
WORLD DISTRIBUTION OF PRECIPITATION. The type and amount of rainfall are closely related to the pressure and wind belts of the world, as well as to their migrations in the course of a year (Illus. pp. 71, 73 and 79).

The total amount of precipitation during the year is, on the average, greatest near the equator. The equatorial belt of low pressure has the heaviest rainfall, the convectional type prevailing. As this belt moves northward and southward with the sun, convectional rainfall is brought to the adjacent belts, where trade winds prevail during the low-sun season.

In the subtropical high-pressure areas, air is predominantly in downward movement. Thus it is warmed, rather than cooled, and relative humidity is low. Considerable land areas in the subtropics, and adjacent portions of the ocean, have little precipitation. In Africa the Sahara region and the neighboring part of the Atlantic Ocean as far as 30 to 35 western longitude has very low rainfall. A similar zone of scant precipitation reaches from Sonora and Baja California in Mexico and southwestern Arizona and southern California in the United States to about 125° west longitude over the Pacific.

In the trade-wind belts, also, precipitation tends to be low, as long as the trades are strong and steady. During the high-sun season, however, the displacement of the trades by low pressures causes convectional rains. Within the trade winds proper, absolute humidity is not low. Thus when these winds encounter high land masses, considerable orographic rain may result, as along the east coast of Brazil, on the mountainous islands of the Caribbean area, and in the East Indies.

In the belts of the prevailing westerlies, precipitation is largely of the cyclonic type. It tends to be greatest along the western, windward margins of the continents. Where the mountain ranges rise immediately back of these west coasts, as in British Columbia and western United States, orographic precipitation on the exposed slopes is heavy, whereas the eastern slopes are dry. This contrast is especially marked in the winter season when the eastward-moving air masses are rapidly cooled as they pass over the cold mountain slopes. Where there are no high bordering ranges, as in western Europe, the moisture is carried farther inland and precipitation is not so heavy near the coast. In the belts of the westerlies, even the east coasts are fairly well watered, because of the moist air carried inland from the oceans by the east and southeast winds which accompany the passage of the cyclonic storms so characteristic of these wind belts. (See map below.)



World map of average annual rainfall.

Precipitation as a climatic element. From a climatological point of view, the average annual amount of precipitation and the seasonal distribution are most important. Also important are intensity of rainfall, variability, and presence or absence of snow.

The annual amount of precipitation is usually stated in inches or millimeters and is popularly referred to as low, moderate, or heavy. In actual practice, we think of rainfall in the middle latitudes as being low when it is less than 20 inches per year. From 20 to 40 inches is moderate, and above 40 inches is heavy. However, these figures do not hold true in areas farther poleward or equatorward. In the former, low temperatures prevail and evaporation is smaller. Thus, a small amount of precipitation may still be sufficient to cause relatively humid conditions. However, in the tropical regions, with their higher temperatures throughout the year, rainfall of less than 40 inches may signify subhumid conditions with many xerophytic plants in evidence. Seasonal distribution is referred to with emphasis upon winter or summer conditions, because in many cases the distribution of rainfall is fully as important as the amount. For example, the agriculture of the Mediterranean lands is based on crops which mature early because summer is characterized by little rain there, whereas in the Corn Belt of the United States agriculture is organized on a basis of summer rains and winter drought. Where the frostless season is of five months' duration or longer, and sunshine is abundant, summer rainfall is conducive to corn as a crop, whereas summer drought prevents successful corn production except under irrigation. As a consequence, the Corn Belt of the United States extends from Ohio to Nebraska in the area of summer rains, while in Spain and Italy, where summer drought is characteristic, early maturing wheat predominates except in the humid north.

The intensity of rainfall often determines its usefulness. For example, gentle rains soak into the ground and thus are much more effective in promoting plant growth than are torrential rains. The latter not only give rise to a lower percentage of soak-in, but also cause heavy run-off and resultant soil wash. A smaller amount of rain falling gently is, therefore, more efficient in furthering agricultural activity than is a larger rainfall of torrential type.

Variability of rainfall is another important factor. In many areas the amount of rainfall may be twice as great one year as another. This is true in some parts of the tropics, where in one year the rainfall may be as high as 140 inches and the following year may drop to 70 or 80 inches. On a percentage basis, however, variability is greatest in many of the arid and semiarid areas of the world. Even our humid eastern United States is subject to damaging dry spells of unpredictable time and length nearly every summer. Great variability, especially in regions of light rainfall, gives rise to difficult problems of agricultural adjustment.

Rainfall is one of the most significant elements of climate. Water is the great solvent by means of which plant and animal foods can be converted into tissues and active energy. Thus, where rainfall is scanty, the possibilities for all sorts of organic life are less than where rainfall is abundant. Vast areas of the land surface have little capacity for production because of insufficient rainfall. In these desert or semidesert regions, vegetation is scattered and is specialized to conserve every drop of water. Leaves are small, often wanting, in which case the stems perform the function of the leaves. Cacti and thorny bush are characteristic examples of arid land vegetation. Crop production may be impossible without irrigation. Over large areas, agriculture must be chiefly of the herdsman type. Fixed habitations are not possible in a pastoral economy; in order to live, animals and man must be able to move swiftly from place to place. It is the land of the fleet and the wary, the gazelle and the nomad. If fleetness is lacking, defense must be relied upon, and horny plates and poison fangs come into play. The horned toad and the Gila monster are forms of adaptation to the land of little water.

Abundant rainfall coupled with high temperatures is conducive to heavy vegetation Part of the Congo basin of Africa and the Upper Amazon Valley of Brazil are drenched with rain and covered with dense jungle. In both areas, however, vegetation is so luxuriant that it seems to smother both animal and human life. A superabundance of precipitation may be a handicap almost as severe as too little rainfall.

Comparison of rainfall and population

maps shows that on the whole the extensive dry lands of the world are sparsely peopled except in cultivated oases such as the Nile Valley; the bulk of the world's population lives where moderate rainfall prevails. Where there is little rain, dearth of foodstuffs is the limiting factor; where rains are too abundant, man is overcome by vegetation and disease. (Illus. pp. 16 and 79.)

Summary. The climatic factors—temperatures, winds, humidity, and precipitation—have various aspects which are of importance to the study and characterization of climate. These aspects differ quantitatively over the world. The numerous possible combinations lead to differences of great importance to natural vegetation and animal life, to soils, crops, human activities, and general modes of living.

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Chapter Six

CLIMATES, VEGETATION, AND SOILS OF THE WORLD

EVERYONE KNOWS THAT EVERY PLACE in the world has a climate peculiarly its own, different in a few or in many respects from that of other sections. The suburbs are reputed to have a better climate than the city, and area near the water may have a better climate than the adjacent hills, or vice versa. Southern Florida and southern California are said by advertising folders to have perfect climates, while the climate of the Guinea coast and other parts of the "deep tropics" is known, at least from the movies, as something inimical to the white man.

The general public, however, rarely tries to apply a yardstick to such real and fancied characteristics or differences. Climatology attempts to do so, although students of climate do not entirely agree as to what yardsticks should be used. Some emphasize average values of certain climatic elements, singly or in combination; some emphasize deviations from the averages, others, relative frequencies of specific weather conditions, still others, prevalence of certain types of air masses.

As does any other science, climatology measures, describes, classifies, and attempts to explain. All four of these go hand in hand, and cannot be separated. Small local climatic differences, such as those between a floodplain and neighboring uplands, or between the suburbs and the city, are the subject of *microclimatological* study, while differences over larger areas are the subject of *macroclimatology*, or climatology "proper." In this chapter we shall be concerned only with the latter.

Classification of climate. Classifications of climates can be based upon different criteria and also can be made for different purposes. For example, one might wish to classify the climates of the world or of a continent from the point of view of aerial navigation. For such a classification, the criteria used would necessarily be different from those needed to classify climates according to the reactions of the human body to atmospheric conditions.

From the economic point of view, the most useful classification is perhaps one which emphasizes relationships between the climatic elements and natural vegetation and crops. If one wishes to extend such a classification over the entire world, it is necessary to choose climatic elements for which values are available in sufficient quantities. A classification based upon frequency of types of air masses, for example, is not as yet possible, for lack of adequate data. Temperature and precipitation data are most readily available for most parts of the world, while quantitative data on wind direction, wind strength, humidity, and evaporation are much less numerous. For this reason the major current climatic classifications depend primarily upon temperature and precipitation data, used singly or in combination.

One major factor affecting the growth of natural vegetation and crops is soil moisture. This is usually derived from precipitation, although sometimes it is provided by ground water or by irrigation. Direct data on soil-moisture content are still very scarce, and for purposes of climate classification it is necessary to resort to precipitation data, modifying the value of total annual rainfall by taking into account average annual temperatures and distribution of the precipitation over the year. Thus, in the middle latitudes average annual precipitation has to drop below about 20 inches before conditions of semiaridity are encountered, whereas in the tropics semiaridity may result when rainfall is less than 35 inches. It is clear that a rainfall maximum which occurs during the warmest part of the year will be less effective as a creator of soil moisture than will a maximum during the coolest part of the year. On the other hand, if temperatures during this coolest part of the year are so low that crops cannot grow, then a rainfall maximum during the late spring and early summer, when most of the vegetative growth of plants takes place, will be more beneficial.

Although the matter is subject to considerable debate, it appears that on the whole temperature distribution is more basic than is distribution of precipitation. Tropical vegetation and crops are radically different from vegetation and crops of the middle latitudes. No such sharp differences exist between the humid and dry portions of each.

The major climatic zones. On the basis of general temperature distribution and differences in the general circulation, we can recognize the following major climatic zones: the tropics, the two subtropical belts, the two belts of intermediate climates, and the two polar areas—seven major zones in all. (See World Map of Climatic Regions at end of book.)

The *tropical climates* have no frosts, except in a few localities at relatively high altitudes; in other words, as far as temperature is concerned, they have an all-year growing season. The average annual temperature is above 77°F. (25°C.) and, except at higher altitudes, the average temperature of all months exceeds 65°F. (18°C.). We should not associate extremely high temperatures with this group of climates, because, except in desert areas, the thermometer rarely reaches 100°F. The tropics are characterized by monotonously warm and often humid weather, with little change from day to night and from month to month. Excessive temperatures, such as those attained on the plains of the interior of the United States in the summer, are restricted to the arid portions of the tropics. In the Americas, tropical climates extend from Mexico and southernmost Florida to a line roughly from Sao Paulo, Brazil, to the southern tip of Paraguay, and from there to Antofagasta, Chile (see World Map of Climatic Regions).

In the Old World the tropical climates extend from southern Algeria, Egypt, northern India, and northern Indo-China to the southern part of Africa and north-central Australia.

The *subtropical climates* have short, mild winters and long growing seasons. There is a period of one to four months wherein freezing temperatures may occur, though the average temperature of the coldest month is above 43°F. (6°C.). The summer temperatures may be fully as high as those of the tropical climates, but each year there is a short period of cooler weather wherein growth of plant life is arrested or retarded. The winters, although not severe, are sufficiently cold to break the monotony of all-year warmth and to stimulate human activity, thus making the subtropical climates desirable from the standpoint of comfort as well as of productivity. During the winter the subtropical areas are in the belt of the cyclonic storms, while in the summer they are located in the "root" areas of the trade winds. They are located immediately to the north and south of the tropical areas.

The *intermediate climates* are those which prevail between the subtropical and the polar, often having both the heat of the one and the cold of the other. The term *temperate,* which originated in western Europe, has become well established for these climates. However, climates such as are found in the interior of the United States or Eurasia can hardly be considered "temperate," and so it seems desirable to discontinue the use of the word.

The intermediate climates are areas of conflict between huge masses of cold air, issuing from the polar regions, and masses of warm air from the subtropical latitudes (so-called "polar air" and "tropical air"). They have cold winters and warm to hot summers. They vary from areas where the winters are short to those where they are long and severe. They all, however, have the common characteristic of a frost-free and a frost-certain season. They are often spoken of as the *middle latitude climates* and, in the minds of most people, are associated with great annual range in temperature and often great diurnal range. These are the climates of rapid weather changes, caused by cyclonic storms. The most extensive areas of intermediate climates are found in the northern hemisphere. In North America, the southern border of the intermediate climates lies in California and from there runs approximately in the neighborhood of the United States-Mexican border to San Antonio, and from there to south of Memphis and Montgomery in Alabama, and Wilmington in North Carolina. The northern border lies in northern Canada.

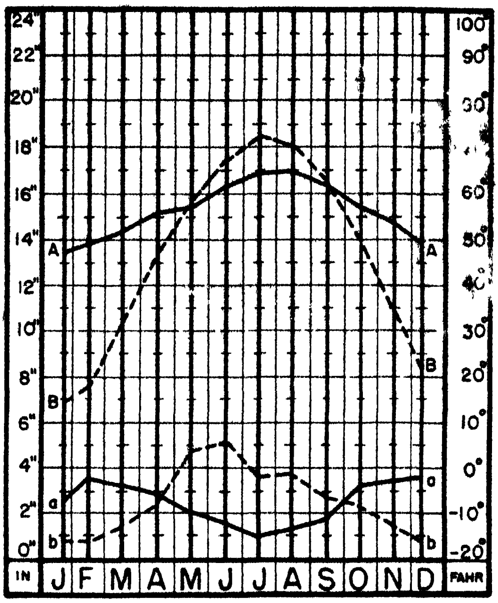
In Eurasia, the intermediate climates reach as far south as northern Spain and Italy, the Balkans, Persia, and northern China, and as far north as the rim of the Polar Sea. (See World Map of Climatic Regions.)

In the southern hemisphere, southern Chile and southern Argentina have intermediate climates, as also have Tasmania and New Zealand.

The *polar climates* are characteristic of the high latitudes. They have long, severe, cold seasons and short summer periods of mild, rather than warm, weather. Freezing temperatures may occur in all months, and the average temperature of the warmest month of the year is below 50°F. (10°C.). They have no true forests, the poleward limits of tree growth being accepted as marking the approximate limits of the intermediate climates. The milder phases of the polar climates are found in the tundra regions of northern Eurasia and North America, whereas the ice caps of Greenland and Antarctica represent the most severe phases. The polar climates are unfavorable to human life; only along their milder margins can man live, and even there the struggle is disheartening.

Effects of large water and land masses. As has been stated on page 67, land and water heat unequally. Air masses formed over or moving over large water areas or uniform land areas gradually take on, at least in their lower levels, some of the characteristics of the surfaces over which they move. Maritime air masses, originating over the oceans, generally contain considerable moisture and are relatively cool in summer and relatively mild in winter. Continental air masses usually contain less moisture, and are relatively warm in summer and cold in winter. These effects are felt in the tropics and subtropics, as well as in the middle latitudes, but are most pronounced in the latter.

In the middle latitudes, *marine climates,* characterized by small seasonal and daily temperature ranges, are found on west coasts, where maritime air masses predominate over continental air masses. Summers are cool and winters are mild. Both the winter minimum and the summer maximum temperatures are usually delayed, February being the coldest month and August the warmest month of the year. High humidity and prevailing cloudiness are two of the most typical characteristics of marine climates. Rainfall is ample and well distributed throughout the year, but with a distinct maximum in the late fall. (See Illus. below.) The marine type of climate is, of course, best developed on islands and on exposed portions of coasts, especially on the west coasts of continents in the middle latitudes—as, for example, on the Hebrides off the coast of Scotland or on the peninsula of Cornwall, England. Such extreme marine climates may be called *oceanic.*



Comparison of average monthly temperatures and average monthly precipitation of marine and continental climates. Marine: La Corina, northwestern Spain; temperature A, rainfall a. Continental: Mason City, Iowa, U. S. A.; temperature B, rainfall b.

The *continental* climates of the middle latitudes have great extremes of temperature, high temperatures being common during the summer and the daytime and low temperatures in winter and at night. The temperature range generally increases, but precipitation decreases with the distance from the ocean. There is much less cloudiness in the continental climates than in those of the marine type, and the prevailing humidity is lower. The interiors of North America and Asia offer the best examples of well-developed continental climates.

The effects of altitude. Great altitude imparts a certain similarity to climates of widely separated regions. *Mountain* climates are characterized by low air pressures and low temperatures. At high altitudes insolation is intense, since the sun's rays have lost but little energy in their course through the thin and dry upper air. Nevertheless, the air in the mountains remains cool because it is thin, clear, and dry, and thus has little absorptive power. The light of the sun contains more ultraviolet rays than at sea level; this, combined with the low barometric pressure and cleanliness of the air, is responsible for the establishment of sanatoria in many high mountain regions. Mountain climates have a typical zonal arrangement of subclimates. As one ascends, winters become longer and colder, and the climate begins to resemble in many respects that of the polar regions. In plateau regions, where altitudes are considerable but within certain ranges, the climate may be uniform and considerably more moderate than in adjacent lowland regions. Especially in the tropics, plateau regions often have more favorable climates for settlement and general economic use. The climates of the world may thus be classified into broad groups on the basis of temperature, and may further be subdivided into *climatic types* on the basis of whether they are dry or humid, whether they have all-year or seasonal rainfall, whether they are continental or marine, or whether they have highland (plateau) climates or mountain climates.

Each climatic type has definite climatic characteristics, typical natural vegetation, and native animal life, and, in many cases, typical crops. Different parts of the world with similar climates often show remarkable similarities in their products and productive capacities.

The scheme of subdivision into types is shown with brief defining statements in the following outline. This outline is presented as a summary of the characteristics of the various types of climate which prevail, and it also presents a brief résumé of the criteria used as the basis of classification. It should be referred to frequently in connection with the more detailed discussions given in subsequent chapters.

THE MAJOR CLIMATES OF THE WORLD

The tropical climates. The all-year warm climates. All months frost-free except on highlands. Average temperature of coolest month is above 65°F. (18°C.), with a few exceptions.

Humid Tropical Climates

1. *Tropical rainy type.* No prolonged and pronounced dry season. Native vegetation characterized by rain forest and jungle having no seasonal leaf fall. In a few cases a pronounced dry season exists, but precipitation is so high that jungle vegetation is possible—e.g., along the west coast of India. Temperatures relatively monotonous, and humidity high. Representative regions: Guinea coast west of Dahomey; Congo Basin; Amazon Basin.

2. *Tropical savanna type.* Rainfall plentiful most of the year, but pronounced dry season during two to four months (winter, or, rather, low-sun season). Native vegetation characterized by tall coarse grasses and scattered trees, often thorny bush. Most trees and shrubs suffer leaf fall during dry period. Representative regions: southern Sudan; much of India; Brazilian upland; Orinoco Basin.

3. *Tropical highland type.* Rainfall similar to that of the tropical savanna in amount and seasonal distribution. This type prevails at altitudes of about 2,500 to 6,000 feet. Temperatures lower, owing to altitude. Generally one to six months below 65°F. (18°C.). Small seasonal range of temperature, but relatively large daily range. Representative regions: Rhodesian highlands; plateau of southeast Brazil.

Dry Tropical Climates

4. *Tropical steppe type.* Rainfall scant. Long dry season and short rainy period yearly. Greater diurnal range of temperature than annual range. Vegetation generally of the xerophytic bush type, acacias common, short grass in some areas. Located poleward of the tropical savanna regions, the more humid aspects constituting the transition zones between savanna and true bush steppe. Representative regions: northern Sudan; Kalahari; and Australian steppes.

5. *Warm desert type.* Average annual rainfall less than 10 inches and of irregular occurrence. Large diurnal range of temperature. Vegetation scant, in places entirely absent. Representative regions: Sahara; Australian Desert; Arabia; Atacama.

The subtropical climates. Average temperature of coldest month is above 43°F. (6°C.), but below 65°F. (18°C.). During cool season, one to four months, temperatures may occasionally drop below freezing point, 32°F. (0°C.).

Humid Subtropical Climates

6. *Humid subtropical type (sometimes referred to as the Cotton Belt climate).* Rainfall averages above 30 inches per year in most regions; no pronounced dry season. Generally four to six months with average temperatures below 65°F. Frost may occur during coldest period. In general, slight interruption of growth due to low temperatures. Prevalent climatic type along east margins of continents in lower middle latitudes. Representative regions: southeastern Australia; River Plate area; southeastern United States; southern China. The climate of southern China is a monsoonal variant from the true type.

Dry Subtropical Climates

7. *Dry subtropical type (Mediterranean).* Average annual rainfall generally below 30 inches, in some places below 20 inches. Rainfall mostly during cool season, summers nearly rainless. About six to eight months with average temperatures below 65°F. Frosts may occur during coldest period, but little interruption of growth, owing to low temperatures. Prevalent climatic type along west margins of continents in lower middle latitudes; generally restricted to low altitudes. Representative regions: southwestern Australia; central Chile; Mediterranean coastal lands; southern California.

The intermediate climates. Have both frost-free and frost-certain periods each year. Hot summers and cold winters are characteristic. Continental phases with pronounced seasonal extremes occur in the interiors of North America and Eurasia, oceanic phases predominate on the west coasts of these continents. Along east coasts are ocean-modified variants from true continental conditions.

Humid Intermediate Climates

8. *Humid continental type.* Average temperature of coldest month below 42°F. (6°C.), but not more than four months with average below freezing point (32°F.). More than three months with average temperatures above 50°F. (10°C.), and growing season free of severe frosts three months and longer. Average annual range more than 36 Fahrenheit degrees (20 Centigrade degrees). Average annual rainfall over 20 inches, with heaviest rainfall during the warm season. Representative regions: central United States; central Europe; northern China; central Russia. This climatic type can be divided into two subtypes. (1) 9 months or longer with average temperature above freezing point (32°F.); (2) less than 9 months with averages above freezing.

9. *East coast continental type.* Occurs along the east coasts of North America and Asia between 35° and 50° N. latitude. Average annual temperatures not greatly different from those of the same latitudes in the continental interiors, but seasonal extremes are not so pronounced. Influence of the ocean carried over the land by cyclonic storms resulting in retarded approach of seasons, in smaller range of seasonal temperatures, and in relatively uniform distribution of precipitation in all months of the year. Heavy winter snows in contrast with the light snowfall of continental interiors. Representative regions: New England; northern Japan.

10. *West coast marine type.* Average annual range of temperature less than 36 Fahrenheit degrees (20 Centigrade degrees). Rainfall abundant and fairly well distributed throughout the year, with tendency toward an autumn maximum. Native vegetation varies from mixed hardwoods to solid stands of conifers. Representative regions: Pacific coast of Washington and British Columbia; southern Chile; west coasts of Europe.

11. *Subpolar type.* More than four months with average temperature below freezing point, and at most three months with average temperatures above 50°F. Rainfall lower than in other humid temperate climates, but efficient because of low rate of evaporation. Includes much of the temperate coniferous forest belt. Representative regions: Finland; northern Russia; Siberia; central Alaska; central Canada.

Dry Intermediate Climates

12. *Middle latitude steppe type.* Low annual rainfall with summer maximum is chief characteristic. Annual rainfall 6 to 20 inches. Wide temperature variation. Low humidity in warmer areas. Natural vegetation in the cool and more humid areas varies from short grass cover to sage brush and scattered bunch grass; in warmer and less humid areas thorny bush and mesquite are dominant over the grasses. Representative regions: the Steppes of southeastern Russia; the Great Plains of North America.

13. *Middle latitude desert type.* Similar to the steppe or semiarid type, except that rainfall averages less than 6 inches per year and vegetation is scantier, varying from scattered thorny bush to complete bareness. Representative regions: Mojave desert of southern California; the Gobi desert of Mongolia.

The polar climates. Average temperature of warmest month is below 50°F., and freezing temperatures may occur in all months of the year. Low temperatures prevent growth of trees. Rainfall largely in form of snow, but, measured in inches of water, is not heavy.

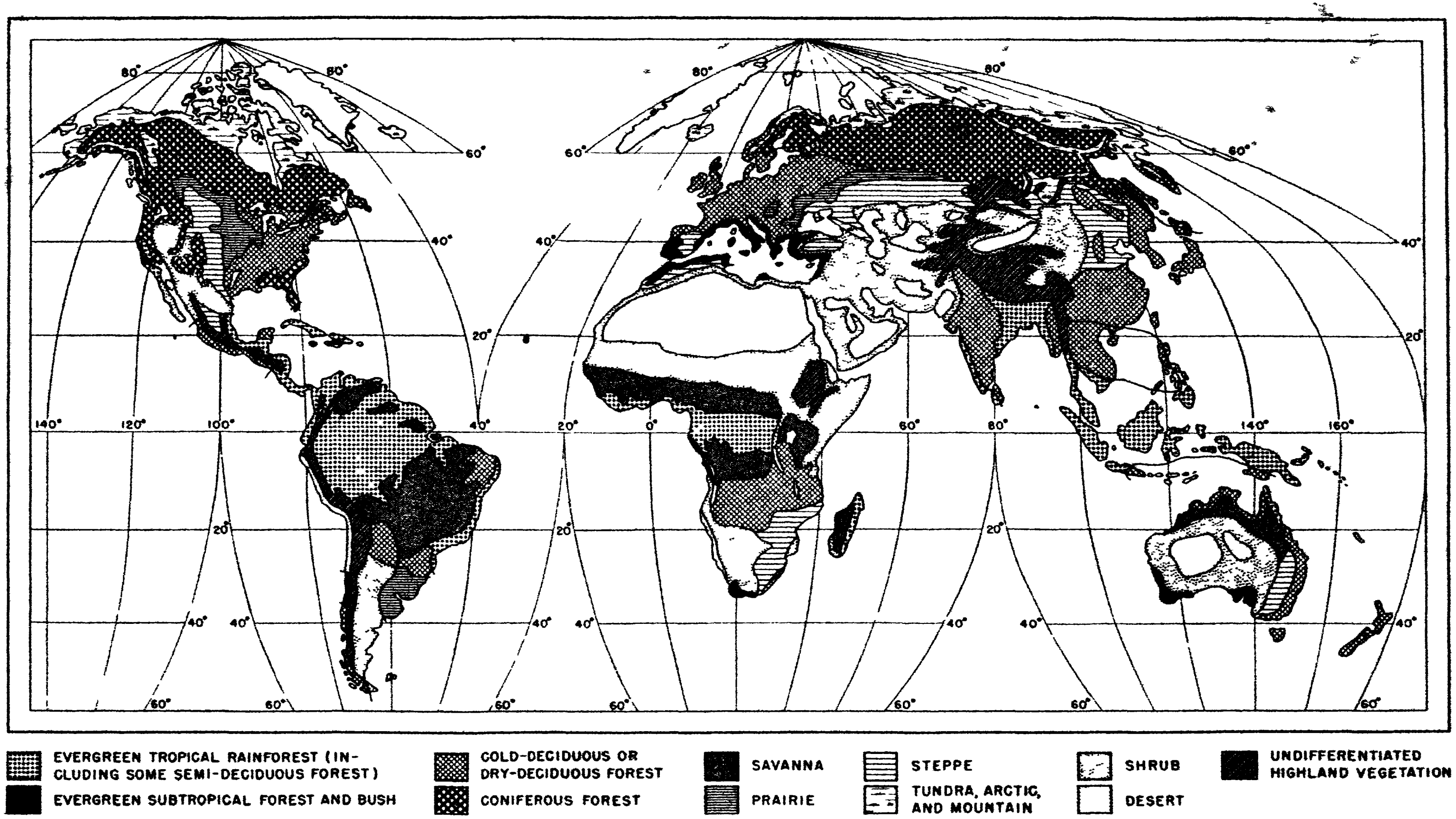
14. *Tundra type.* Average temperature of warmest month is above freezing but does not exceed 50°F. Some vegetation of moss and scrub-bush kinds. Representative regions: northern North America and northern Siberia.

15. *Ice-cap type.* Average temperature of warmest month below 32°F. No vegetation. Representative regions: Greenland; Antarctica.

The mountain or high altitude climates

16. Mountain climates are characterized by such a variety of differences, owing to local conditions, that definite criteria cannot be established nor any specific general characteristics be described. In temperature they range from tropical to polar, and in vegetation from rain forest to desert.

Climates and vegetation formations of the world. As has been stated repeatedly in this and preceding chapters, there is a close relationship between the major aspects of vegetation and climatic conditions. This relationship is so close that names of vegetation formations are used frequently for climatic types, such as *savanna* and *steppe* climate.


80°
60°
40°
20°
140°
120°
100°
40°
20°
0°
60°
80°
140°
160°
EVERGREEN TROPICAL RAINFOREST (INCLUDING SOME SEMI-DECIDUOUS FOREST)
EVERGREEN SUBTROPICAL FOREST AND BUSH
COLD-DECIDUOUS OR DRY-DECIDUOUS FOREST
CONIFEROUS FOREST
SAVANNA
PRAIRIE
STEPPE
TUNDRA, ARCTIC, AND MOUNTAIN
SHRUB
DESERT
UNDIFFERENTIATED HIGHLAND VEGETATION

A generalized map of the major vegetation formations of the world In many parts of the world these formations have partly or wholly disappeared due to man's activities.

The vegetation formations of the earth can be classified broadly into four major types: (1) forest, (2) savanna, (3) grassland, and (4) shrub. Since the climatic conditions which are largely responsible for the distribution of these types do not have sharp boundaries, the formations are usually not separated by any sharp lines. Therefore, it is not possible to define the exact margins of the various types or of their subtypes, but lines are established to mark the places where one ceases to predominate and another becomes dominant (see Illus. p. 88).

In general, forests occur in regions of heavy to moderate rainfall, grasslands and savannas occur where rainfall is moderate to light, and deserts occur where the rainfall is scant. These generalizations will be found helpful in correlating vegetation with climate in the different parts of the world.

Since the native vegetation is of such importance, not only as a fundamental economic resource but also as an indicator of possible utilization of the land, we should learn to think of it systematically. The larger divisions and their principal subdivisions can be described in rather simple terms. Such descriptions enable us to see more clearly the relationships among the divisions and the environments in which they occur. The outline which follows is designed to serve such purpose.

1. *Evergreen Tropical Rain Forest*

This type of broad-leaved forest is found in the rainy lowlands of low latitudes, as, for example, in the Congo Basin and in the lower Amazon Valley. The trees have no periodic leaf fall and the forest is ever clothed with verdure. Numerous varieties of trees and mixed stands are the rule. It is predominant in climatic type 1. (See page 86.)

2. *Evergreen Subtropical Forests*

In this class belong the stands of evergreen trees in lands with Mediterranean climate. These occur where there is summer drought and moderate winter cold and consist of species which have developed tolerance of such conditions. (See map on page 88.)

3. *Deciduous Forests*

This type of broad-leaved forest is characterized by periodic leaf fall induced either by drought or by freezing temperatures. Wide distribution is characteristic, notable examples being found on every continent. Among the best known are the mixed hardwoods of eastern United States, such as the oak-hickory forest or the beech, birch, and maple forest. There the leaf fall is induced primarily by the freezing temperatures of approaching winter. On the other hand, deciduous broad-leaved forests are found in India parts of Australia, and along the west coast of Central America where seasonal drought induces leaf fall. Teak forests are typical tropical deciduous forests.

4. *Coniferous Forests*

This type of narrow-leaved forest is widely distributed over the continents. It occurs at moderate to high altitudes in the low latitudes, where elevation causes climatic conditions such as are characteristic of middle latitudes. The most extensive areas, however, are in the middle latitudes, where vast forests of almost solid stands of pine, spruce, or fir occur. Notable examples of this type are the pine forests of southeastern United States, the fir of the northwest, the spruce of Canada, and the several kinds of coniferous forests of Scandinavia and Russia. It is predominant in climatic type 11.

5. *Savannas*

This type consists of stands of tall, coarse grasses wherein are found scattered trees or clumps of trees, particularly in the warmer latitudes. Savannas may be considered to be transition zones between the forests and grasslands of low latitudes, although the term is also used to include some wet grasslands in the middle latitudes where scattered tree growth occurs. Perhaps the best-known example of an extensive savanna area is the Sudan of Africa. It is predominant in large parts of climatic type 2. (See page 86 and map, p. 88.)

6. *Prairies*

These areas of tall grass occur in the middle latitudes. Tall grasslands are the response to moderate rainfall, generally above 20 inches per year. In such areas the growth period lasts throughout a fairly long summer and is terminated by the low temperatures which mark the advent of winter. The prairies of the central Mississippi Valley, the Pampas of

Argentina, and the Black Earth Belt of Russia are the best-known examples. Most of these areas have been turned into agricultural land.

7. *Steppes*

These short-grass regions of the middle latitudes occur where the annual rainfall ranges from 10 to about 20 inches a year and comes mostly in the spring and early summer. The grass dies down without harvesting, thus furnishing brown pastures throughout much of the season of drought. The best-known examples are the Great Plains east of the Rocky Mountains and the extensive steppes of southern Russia.

8. *Tundras*

This is not a true grassland, but its resemblance thereto is marked. The tundra is limited to areas wherein cool to cold weather occurs all year and evaporation is so slow that even moderate rainfall gives rise to relatively humid atmospheric and soil conditions. The vegetation is low and sprawling, mostly grasses, annuals, mosses, and very low shrubs. The tundra areas of northern Siberia are the most widely known, but similar conditions prevail over large areas of northern Canada.

9. *Shrub*

Shrub vegetation occurs generally where poverty of the soil, strong winds, or low rainfall make impossible normal tree growth The drought-resistant shrub of the Mediterranean region called *maquis*, or *macchia*, is one typical form, as is the *mesquite* of southwestern United States. Other poorer forms are the scrub formations of some of the semiarid tropical regions such as the Sudan and parts of Australia. Poorest of all is the desert shrub.

Soils as the products of climatic and vegetation conditions. The most valuable part of the earth is the surface film of soil, only a few inches to a few feet thick. If this thin veneer should disappear, food plants could not grow, land animals would starve to death, and the few remaining human beings would have to cling to the coasts competing for the insufficient seafood. There would be no lumber for houses or newspapers, no cotton, wool, rayon, or leather for clothing. Yet, in the United States alone, unwise land use since the arrival of the white man has ruined enough of this precious veneer to render millions of acres of cropland unfit for cultivation. In large parts of the world no adequate steps have been taken to preserve the topsoil. The first step toward wise soil-use policies is an understanding of soil itself

Not all loose, unconsolidated earth materials are soil, but only the highly weathered earth material which has been influenced by climate and plant growth can be called so.

Thus, the soil is the upper part of the mantle rock, which as a result of physical and chemical changes—owing to weathering, the leaching and depositional activities of soil water, the presence of decaying vegetable and animal matter, and other factors—has developed certain characteristics of its own. This development often makes the soil into something quite different physically and chemically from the underlying material from which it was derived.

Thus, different underlying, or parent, materials may have soils which are quite similar. However, one should not go so far as to deny the importance of the nature of the parent material. In the Shenandoah Valley of Virginia, for example, the soils developed upon the limestones differ greatly in agricultural value from those developed on the shales. Similarly, soils developed upon sands can never be the same as those developed upon adjacent clays.

Characteristics of soils. Among the qualities of the soil most commonly recognized and discussed are texture, structure, thickness, color, and the presence or absence of hard layers, known as *hard pan*, near the surface.

Texture refers to the size of the particles which constitute the soil or any other natural earth substance. If the texture is too coarse (coarse sand), the soil is quite likely to let water pass through too rapidly and thus be droughty; if too fine (clays), the soil becomes too compact, drains too slowly, and is difficult to cultivate successfully. Soils which are medium textured (loams) tend to absorb and retain moisture, are readily tilled, and hence give rise to favorable agricultural conditions.

By ***structure*** we mean the arrangement of the soil particles within the mass. Studies during recent years have revealed this as a most important property in accounting for soil differences. It involves factors too complex for detailed treatment here, but in a simple way we may think of soil particles as being arranged in thin layers or plates, rough cubes, small columns, irregular granules, or as having no arrangement at all. The water-holding capacity of the soil, its adaptability to cultivation and even its productive capacity are, in most cases, directly related to its structure.

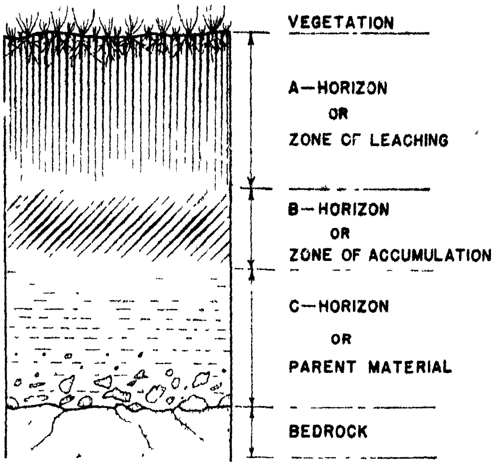


Diagram showing soil horizons.

The *color* of a soil depends upon its mineral and organic content. In general, brown and reddish soils owe their color to the presence of *iron oxides,* of which ordinary iron rust is the most common example. Dark-colored soils, approaching black, are usually rich in *carbon,* generally referred to as organic matter. Color in itself is not proof of fertility, but generally people prefer dark-colored soils because organic content is essential to vigorous growth of most plant life.

In vertical section, we usually recognize three more or less distinct layers commonly referred to as the "A," "B," and "C" horizons. (See Illus. left.) Near the surface, plant and bacterial action tend to incorporate humus with the soil. In a period of time the upper layers become so changed that they bear but slight resemblance to the original materials. This highly altered zone is commonly termed the "A" horizon. It is best developed, as to quality and depth, in the soils of the temperate climatic belts in which the rainfall is moderate.[1]

Below the A horizon is usually a layer, termed the "B" horizon, of varying thickness wherein only partial alteration of parent material has occurred. There, however, some properties have developed which differ from both the overlying and underlying zones. There may be differences in texture, color, compactness, or content which give rise to a well-defined layer related to the parent material yet differing from it and bearing similar relationships to the overlying more completely altered layer. The B horizon is commonly termed the *subsoil.*

Underneath the B horizon is the unaltered parent material, termed the "C" horizon. In popular language, people often say that the subsoil extends to bedrock. Where the mantle rock is shallow, this may be true, but where it is deep, as, for example, on the extensive alluvial plains or on the loess plains of the Middle West, the lower portion is parent soil material rather than subsoil and therefore should be referred to as the "C" horizon.

It has been generally recognized that soils pass through cycles of development. On the basis of this observation soils may be referred to as *young, mature,* or *old,* according to the stage of development they may have reached.

Young soils are incompletely developed and often occupy slopes, where erosion prevents further development, or they occupy floodplain areas where the cycle of evolution is frequently interrupted by deposition of new sediments.

Mature soils are those which, undisturbed by erosion or deposition, have acquired characteristics distinctly different from those of the underlying material. Such soils occur mostly on well-drained, rather level surfaces, on terraces, and on smooth to gently rolling upland areas.

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[1] Rainfall of about 25 to 40 inches.

Old soils have reached a stage in their development in which their characteristic features are well expressed and exist where they have remained undisturbed for long periods of time. Young, mature, and old soils may exist in the same region, side by side, and represent only different stages in the same evolutionary process.

Major soil groups. The evolutionary processes are not the same in all parts of the world. Various schemes of classification have been suggested by different writers, most of them rather complicated in order to accommodate the many types of soils which are known to exist. The great "zonal" soil groups, recognized first by Russian scientists, have since been studied in other parts of the world. The American system of soil classification is in essence derived from the Russian morphological classification and is based primarily upon visible and physical characteristics of the soils, with secondary attention paid to the chemical characteristics.

The major soil groups of the world as known at present are the following:

1. TUNDRA SOILS. These soils have dark-brown peaty layers at the surface, over grayish horizons. Often parent material underneath is permanently frozen. They occur in high latitudes, under tundra vegetation.

2. PODZOLS. A thin layer with poorly decayed organic material lies on top of a badly leached grayish horizon, under which lies a dark-brown layer, often quite consolidated. This type of soil occurs in higher latitudes, in regions of cold and moist climate. The natural fertility of these very acid soils is low.

3. GRAY-BROWN PODZOLIC SOILS. The arrangement of layers is essentially the same as in the podzols, but the soil is not so acid; the top layer is thicker and contains more humus, which is not so raw as in the case of the podzols. These soils develop under deciduous and mixed deciduous-coniferous forest, in areas of moist climate with a cool to cold winter. Their fertility is medium.

4. YELLOW AND RED SOILS. These soils have a rather thin layer containing organic materials, which rests upon a yellowish brown leached horizon, which in turn lies on a deep-red or yellowish layer. The reddish soils were developed primarily under deciduous forest, and the yellow soils under coniferous forest, in areas of moist and warm climate of the lower middle latitudes. Their fertility is from medium to low.

5. LATERITIC SOILS. These soils have little organic material in the top layer, and what there is is well decayed. Leaching has affected not only the plant salts and the lime but has also attacked the silicates. The upper layers have low silica content but high content in aluminum and iron hydroxides. They are soils of humid tropical regions. Their fertility is low.

6. PRAIRIE SOILS. These are deep, very dark brown soils, which get lighter colored at a depth of from three to five feet, where they grade into lighter colored parent material. They develop under the tall-grass prairies of the middle latitudes, where not too humid conditions prevail. These soils are nearly neutral in reaction, and of high fertility.

7. CHERNOZEMS. These soils have a very dark brown, almost black top layer, which is from one and one-half to four feet thick, and is underlain by a light-colored horizon rich in lime, and often with whitish lime streaks. They develop under tall-grass prairie of subhumid regions in the middle latitudes. Their fertility is high, but their productivity is often considerably reduced by insufficient soil moisture.

8. CHESTNUT AND BROWN SOILS. These are dark-brown to brown soils, decreasing in thickness as the color becomes lighter. The dark layer is underlain by a whitish horizon rich in lime. These soils are typical for steppe regions in the middle latitudes. Fertility is high, but productivity is impaired by droughts.

9. **Sierozems and desert soils.** These soils are grayish and low in organic matter. A highly calcareous horizon often lies close under the surface. The fertility of the soils may be from medium to high, but in order to produce, irrigation is necessary.

Soils rich in lime—that is, soils that are lime-accumulating in the upper horizon—are called *pedocals*, whereas soils characterized by a relatively high iron and alumina content, and which are not lime-accumulating as a result of leaching by soil water, are called *pedalfers*. Pedalfers usually tend toward acidity, whereas pedocals give alkaline reactions. In any mature soil the amount of lime is directly related to the moisture conditions under which the soil has been developed. The mature soils in arid and semiarid areas are generally rich in lime, but in areas of abundant rainfall they are deficient. Since rainy lands usually are forest covered, whereas subhumid lands are prairies and steppes, the pedalfers are known also as *forest soils* and the pedocals as *grassland soils*. But in such a generalization we must recognize the exception of the prairies of the United States which are grassland soils but are not lime-accumulating.

Since lime is needed by most agricultural crops, its presence in the soil is a mark of fertility. Besides, if lime is present in plentiful quantities, other soluble minerals essential for plant growth—such as phosphates, nitrates, and potash—are usually also available more or less abundantly. Such soils rank high in fertility for two reasons: (1) the essential mineral constituents are present in such form and in such quantities that they can serve as plant foods, and (2) the presence of such minerals is conducive to a stable soil structure, favorable for both tillage and plant growth. Acid soils, on the other hand, are weak in the essential plant foods named above, and usually their physical structure is less favorable for tillage and for the production of grain crops and legumes than is that of the soils that are rich in lime.

Soil conservation. In order to obtain the benefits of large and permanent production of crops, man must conserve the soil. In the first place, the soil itself must be protected against sheet erosion, which is an accelerated form of normal erosion, and gully erosion. No greater quantity of soil should be allowed to erode than is normally replaced by soil-forming processes. In furtherance of this aim, steep slopes should be used only for woods or pasture or, if cultivated, should be carefully terraced; even gentle slopes should be cultivated in a horizontal direction, the rows following the slope contour instead of running up and down the slope; and any gullies should be promptly checked.

Even when the soil is kept in place by such means, and in flat-lying soils not subject to erosion, there is need for another type of soil conservation—the maintenance of soil fertility. Any soil, except that annually replenished by natural floods, will eventually decline in fertility if crops are removed year after year. The careful saving and return to the soil of all animal and human excrement has long been the rule in densely settled farmlands such as those in China and parts of Europe. Green manures and fertilizers are widely used in all countries which carry on commercial farming. Rotation of crops may slow up the loss of certain elements from the soil, which so often results in chemical unbalance. Where insufficient manure is available the raising of plants that extract nitrogen from the air (legumes) and accumulate it in their root system as well as the plowing under of green crops, help greatly to maintain and improve both the fertility and structure of the soil.

The application of known methods of soil conservation is dependent upon education and help for the farmer: a process that has made long strides in this country through the use of such devices as land-use planning in soil conservation districts.

From the foregoing it is clear that there are close relationships between general climatic conditions, major natural vegetation formations, and the general characteristics of soils. Similarly, there are close relationships between all of these and the major types of agricultural activity that man can carry on successfully, and the crops he can grow, even though in many regions certain aspects of agriculture are due to prevailing economic and social conditions.

Thus a classification of climate which takes into account these relationships—as does the classification outlined in this chapter—offers a suitable basis for a large-scale regional division of the world from the point of view of agricultural production. Areas of similar climates, natural vegetation, and soils often have fairly similar agricultural potentialities and often have to face fairly similar basic physical problems. In many such areas present agricultural production—the result essentially of basic physical conditions plus certain economic and physical factors—may show points of marked similarity.

It is for this reason that the discussion of the agricultural resources of the world which is contained in the following chapters is based upon major climatic regions, rather than upon such arbitrary physical regions as continents or political divisions.

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Chapter Seven

THE REGIONS OF HUMID TROPICAL CLIMATES

THE WARM CLIMATES ARE OF SPECIAL interest because they are so different from those with which most of us are familiar. We are accustomed to marked temperature changes from summer to winter; the tropical climates have no such seasonal extremes. We are accustomed to rapid changes from cold to warm or vice versa; such changes are rare in the tropical lands. When the bitter cold of winter comes to the middle latitudes it is alluring to think of a climate that is always warm. Nevertheless, the monotony of the continual warmth and dampness of the tropical rainy regions is anything but beneficial to man, whether he be white, brown, or black.

That man is greatly affected physically by his climatic environment is beyond question. For example, the temperature of the inner parts of the body is about 99°F., while that of the skin is 92°. Thus, the body loses heat to the skin, and if the outside temperature is below 92°F. the skin loses heat to the atmosphere. This loss of heat is necessary, as the body, even when at rest, continues to generate heat to an approximate amount of 80 kilogram-calories per hour. Without loss of heat, overheating, resulting in collapse and death, would follow. Normally, when outside temperatures are considerably lower than 92°, man loses a great deal of heat if not clothed. Heat is lost through the necessary warming of food, drink and air intake, and through the evaporation of water in respiration, but on the average as much as 80 per cent of the heat loss is through the skin, by radiation, convection, and evaporation of sweat.

Thus it may be seen that the necessary heat loss takes place most easily in regions of cold and cool climates, and fairly easily in warm regions with low humidity where evaporation rates are high. In fact, in cold weather, even when man is working hard and thus is generating extra calories of heat, excessive heat loss must be prevented by suitable clothing. In very cold weather heat-generating physical activity becomes essential in order to prevent excessive heat loss, no matter how heavy the clothing is.

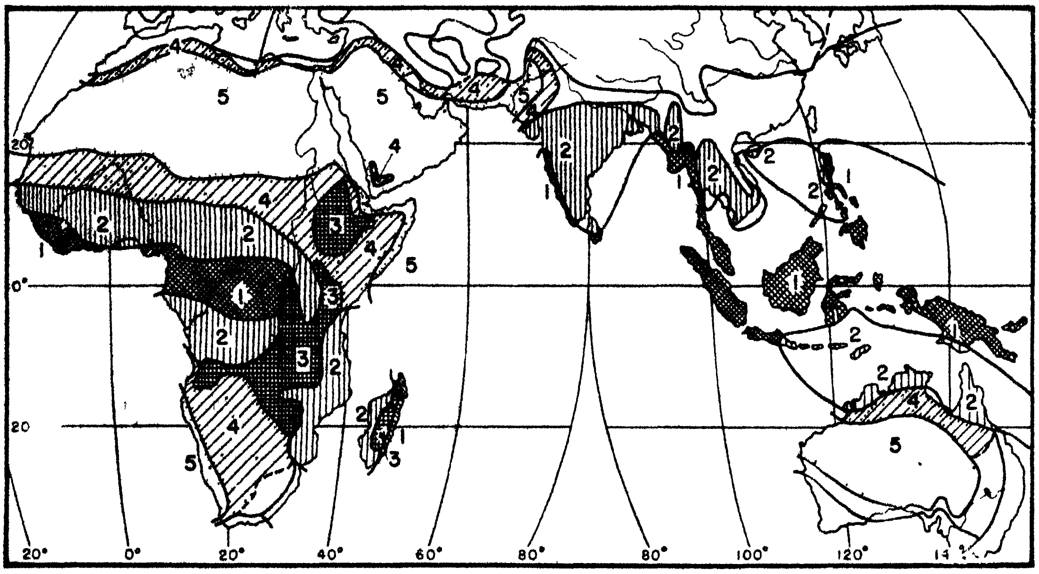
In warm, moist climates it becomes more difficult to lose the necessary amount of heat, especially when much heat is generated as a result of arduous physical activity. Losses through radiation are lower, and particularly when the relative humidity of the surrounding air is high, and there is little air movement, the losses through convection and evaporation of sweat are greatly reduced. Thus, in the humid tropics, even though man may be but partly clothed, extra body heat developed by muscular activity becomes disagreeable, and dangerous even, much sooner than in areas of cool climate, as the excess often can be lost only through more copious perspiration.

It does not seem strange, then, that man in the humid tropics is generally less energetic and displays less initiative than does his brother in the cooler and colder middle and higher latitudes.

The humid tropical climates form a broad equatorial band around the earth, extending beyond the Tropics of Cancer and Capricorn in some areas, and not quite reaching them in others. (See World Map of Climatic Regions, Map above, and Illus. p. 79.) As to their general characteristics, let us at the outset dispel two commonly held notions: (1) that they are excessively hot and (2) that they are always rainy. Contrary to popular belief, temperatures are not often excessively high. Higher temperatures usually occur in the interior of the United States during the months of July and August than are ever encountered in most places near the equator. On the other hand, there is no cold period. The place of summer and winter of the higher latitudes is often taken by decided wet and dry seasons. Sometimes the dry season may be so pronounced that it causes general leaf fall and even cessation of ordinary agricultural activities. Some of the less humid portions of the humid tropics, especially the drier margins of the areas of savanna climate, might even be classed as subhumid because of the long duration of the dry season.

On the whole, the greatest amount of annual rainfall occurs in the equatorial belt. From here it decreases both northward and southward. But even where the rainfall exceeds 100 inches, most of it comes as heavy showers, often in late afternoon or at night, while brilliant sunshine prevails during most of the daytime. This is an important factor in accounting for the rapid growth of vegetation in such areas The equatorial phases of the tropical climates are often warm and humid month after month, a condition that proves quite enervating, particularly to those who are accustomed to the invigorating influences induced by quick changes from warm to cool or cold.

Within the belt of humid tropical climates three major climatic types may be recognized, each extending over large areas



Regions of tropical climate in the Old World 1 Tropical rainy type 2 Tropical savanna type 3 Tropical highland type 4. Tropical steppe type. 5 Warm desert type

These are: (1) the tropical rainy type (areas marked 1 on the climatic map), where all the months are warm and rainy without any pronounced dry season and where the daily and annual ranges of temperature are slight; (2) the tropical savanna type (areas marked 2 on the climatic map), with pronounced wet and dry seasons, sometimes subhumid in character and with somewhat greater annual temperature range; (3) the tropical highland type (areas marked 3 on the climatic map), having all-year warmth, with somewhat lower average temperatures, small annual range but marked diurnal range of temperature.

The Tropical Rainy Type of Climate

(Areas marked 1 on World Map of Climatic Regions, and on Illus. p. 96.)

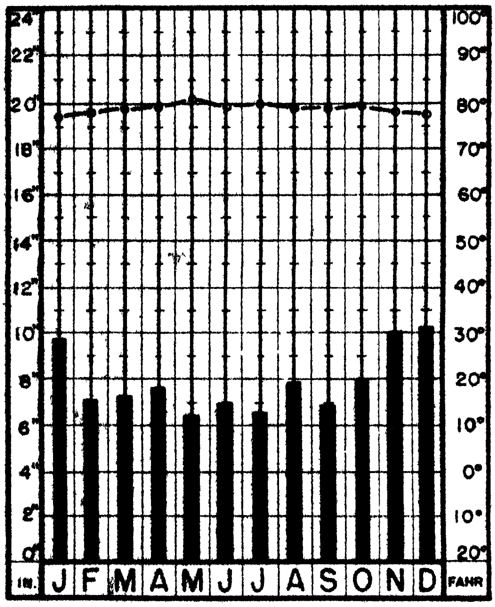
The principal characteristic that distinguishes the tropical rainy from other types of tropical climates is the absence of a pronounced dry season. In general, regions having this type of climate are located in the equatorial belt, ranging a few degrees north and south of the equator. The three major regions that come under this classification are: (1) the East Indies and the adjacent portions of Asia; (2) the Congo Basin and Guinea coast of Africa; and (3) the Amazon lowland and Guiana coastal region of South America. All owe their climatic characteristics chiefly to their location near the equator. Here, annual insolation is highest, the heated, expanded, moisture-laden air rises, and adiabatic cooling produces heavy precipitation.

Smaller areas with essentially the same type of climate occur along tropical east coasts where the trade winds, blowing onshore from warm oceans, are forced to ascend mountains or plateaus causing heavy orographic rainfall, as in Brazil, the West Indies, Central America, and eastern Madagascar. In southeastern Asia, such strips of high orographic rainfall are caused both by the trade winds and the monsoonal winds. In numerous instances the lowlands up to 1,000 feet are desertlike, while the higher slopes are rain drenched. This is notably true along the north coast of Venezuela and part of the east coast of Brazil.

Temperature characteristics. The temperatures are not exceptionally high, averaging generally about 75° to 85°F. Monotony is the dominant feature. The difference between the average temperatures of the warmest and the coolest month rarely exceeds 5°, and in some cases is only about 2°F. The diurnal range is ordinarily greater than the annual range, but in some districts nights are less than 10° cooler than the midday periods. Temperatures above 90°F. are not common, but on the other hand even the coolest nights seldom drop to 60°, and for long periods temperatures of 75° or more may prevail at night.

Pressure and winds. The tropical rainy type of climate is characterized by light winds and calms. The middle portion of this belt is the area of equatorial calms, where the general air movement is one of slow ascent and surface winds therefore are light and variable. Squalls and thunderstorms of short duration occur frequently. Tropical hurricanes are not characteristic of the all-year rainy areas; this is a factor of great economic significance for tropical commercial agriculture.

Rainfall and humidity. Relative humidity is generally high. In many areas it averages 80 per cent or more, and periods of 90 per cent are not uncommon. The total annual rainfall is ordinarily in excess of 60 inches, and some places have 150 to 200 inches a year. The rain comes at fairly regular hours during the day, mostly as heavy showers which last but a short time and are succeeded by brilliant, almost dazzling, sunshine. The more prolonged rains occur at night, but the latter part of the night is not rainy, and the morning hours are usually clear. Even where the rainfall is heavy the percentage of sunshine is high; this combination of abundance of rain, much sunshine, and persistent warmth promotes the dense growth of vegetation so characteristic of areas having this type of climate. In Singapore, as may be seen from Illus. below, during practically all months of the year average temperatures are close to 80°F. This even march of temperature is caused partly by the fact that the city is almost entirely surrounded by water bodies.

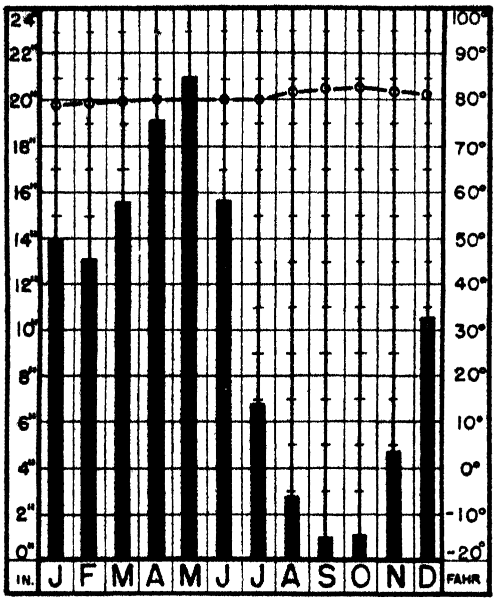


Tropical rainy climate. Average temperature and precipitation, Singapore. Altitude 15 feet, total precipitation 95 inches.

Also, the variation in monthly rainfall is small. In French Guiana (see Illus. right) the temperature march is not very different from that of Singapore, but the rainfall distribution shows distinct seasonality. However, the dry season, in September and October, is rather brief, and the rainfall during the largest part of the year is so high that the climate still is in essence a rainy, tropical climate.

The outstanding features of the tropical rainy climate may be summarized as: winds gentle, temperatures warm and monotonous but not hot, and rainfall abundant, varying seasonally and from year to year but with most months quite rainy. Where so-called dry seasons occur, they are neither prolonged nor severe, and some rain usually falls even in the driest month. The monotony of temperature and the lack of sharp changes becomes tiresome especially to the white man and the difficulty of adequate body heat loss during the warmest hours tends to reduce the desire of people—white, brown or black—to work zealously and at high speed. "Eternal summer" sounds delightful, but in the long run the even temperatures of the tropics are not so pleasant as the ever-changing temperatures of the middle latitudes. The variable weather of the middle latitudes is invigorating; the eternal summer of the tropics is enervating.

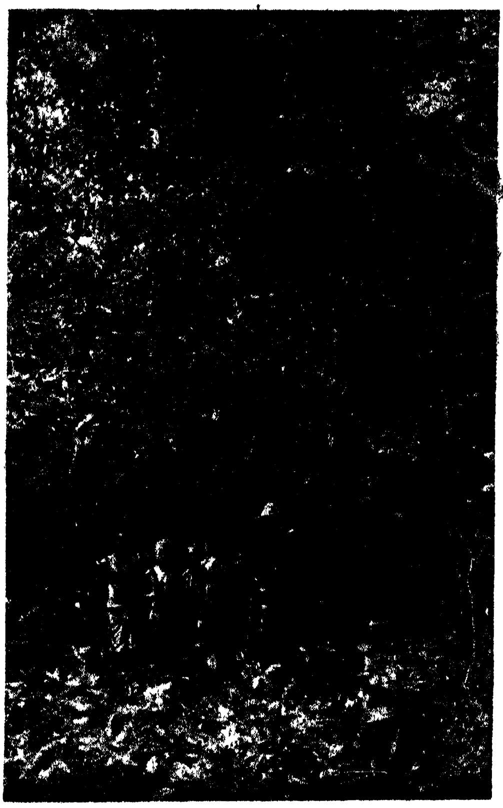
Native plant and animal life. The climatic conditions just described quite naturally result in a luxuriant growth of vegetation, varying from rain forests, where the tree growth is so dense as to leave but little opportunity for underbrush, to the tropical jungle, with its maze of trees, shrubs, and vines. In the tropical rainy regions there are no common periods of flowering and fruitage for all the vegetation, and there is no distinct seasonal leaf fall. Broad-leaved evergreens characterize the land-



Tropical rainy climate. Average temperature and precipitation, Cayenne, French Guiana. Altitude 18 feet, total precipitation 126 inches.

scape. The forest consists of a mixture of a bewildering variety of species quite in contrast to the stands with one or a few dominant species which are typical for the forests of higher latitudes. (See Illus. below.)

Since dense vegetation dominates the land, much of the animal life has adapted itself to living in the trees. The fauna includes numerous flying or climbing types—such as monkeys, snakes, birds, and insects—and there are few strictly ground-dwelling species and almost no burrowers. The birds and insects are characterized by brilliant, even gaudy, colors, among which reds, blues, and greens are the most common. The streams harbor reptiles and mammals as well as many species of fish. Here is the home of the alligator, the crocodile, and, in Africa, the hippopotamus. Abundance of vegetation ordinarily fosters abundant and varied animal life, but the dense jungle furnishes such admirable hiding places that an uninitiated traveler is likely to see little evidence of the numerous animals which watch him from their sheltered retreats. Thus the stranger in the jungle is led to believe that the uncanny silence in which he finds himself is indicative of scarceness of animal life, while as a matter of fact his every movement is being watched by many eyes.



Equatorial forest vegetation in the Belgian Congo. Note dense undergrowth and the vine-like lianas suspended from the branches of the trees.

The soils of the rainy tropics. In the humid warm tropics, where average temperatures are over 78°F., the destruction of humus material tends to be faster than its formation. Thus tropical soils are often short in nitrogen, especially after the destruction of the forest, the main supplier of humus. This low content in humus substances increases the ease with which the plant salts and also the silica can be removed. Owing to heavy precipitation and relatively high temperatures throughout the year, the soils are subject to continual and vigorous leaching. The leaching processes, besides washing out plant nutrients, attack especially the silica of the silicate minerals. If the process goes far enough, little may be left but an infertile mixture of aluminium hydroxides and iron hydroxides, with a very slight admixture of humus. These processes of intense leaching are characteristic of all regions of humid tropical climates, and they lead to the formation of various types of so-called *lateritic* soils, even of pure *laterite*, the infertile mixture referred to above. While laterite probably ranks as the poorest soil in the world, the lateritic soils, in which the processes of leaching have not yet reached the final phase, also are usually deficient in many or all of the essential plant foods and often have poor physical structure.

The color of the lateritic soils is generally yellowish to reddish brown in their upper horizon, except for a thin layer at the top colored dark by humus. Below this follows at varying depths a dark ochre-yellow or mottled yellow and red horizon, which is rich in iron and quite compact. Farther down follows a still harder horizon where the material has been cemented by silicates washed in from above. Usually these soils are heavy, and they become hard and compact upon drying. In a few cases it is necessary to use dynamite in order to break them up for proper aeration. Great care must be taken not to plow or otherwise stir them when they are too wet.

Some real laterites are found on old, badly leached upland areas in the rainy tropics, such as in parts of Borneo and Sumatra, in the interior of the Congo basin, along the Guinea coast, in parts of the Amazon basin, and in the Guianas. Fortunately, true laterites, though widely scattered, are not of large extent.

Where the lateritic soils periodically dry out—that is, where a pronounced dry season occurs—the yellowish or brownish colors of the upper horizon are replaced by a bright red. Until recently this bright red color was considered indicative of pure laterite (Latin, *later* = brick), but at present many of these soils are classified as *tropical* or *lateritic red soils*. Their principal area of distribution lies within the regions of tropical savanna climate.

In general, tropical soils are not so fertile as they have been described by some writers, whose observations were limited to the young alluvial lands bordering the streams. For successful agriculture, liberal applications of fertilizer are desirable and often necessary, and careful methods of tillage must be employed if productivity is to be maintained for more than three or four years after the clearing of the virgin forest.

In the tropical rainy regions there are, however, two general groups of highly productive soils: (1) the young upland soils that result from the rapid weathering of recent lavas of low acidity, and (2) the alluvial soils which have recently been built up along many of the stream courses, or which have been washed down from the mountains and deposited as alluvial fans, in some cases merging into piedmont plains. Java and the rainy slopes of the Hawaiian Islands are well-known examples of the former; and the eastern coast of Central America, the famous banana land, is an illustration of the latter. In both Java and Hawaii recent volcanics with varied mineral content, but of low acidity, weather so rapidly that agriculture is favored by unceasing liberation of soluble salts. Such lands produce abundantly, whereas older soils, similarly tilled, give small returns.

Agriculture. The climate, the dense forest, and the generally poor soils are the most important environmental factors in retarding agricultural development in the tropical rainy regions of the world. Tropical forest areas are difficult to clear; trees are large, much brush must be chopped out, and unless constant vigilance is practiced, the latter soon reclaims the land because of its vigorous, incessant growth.

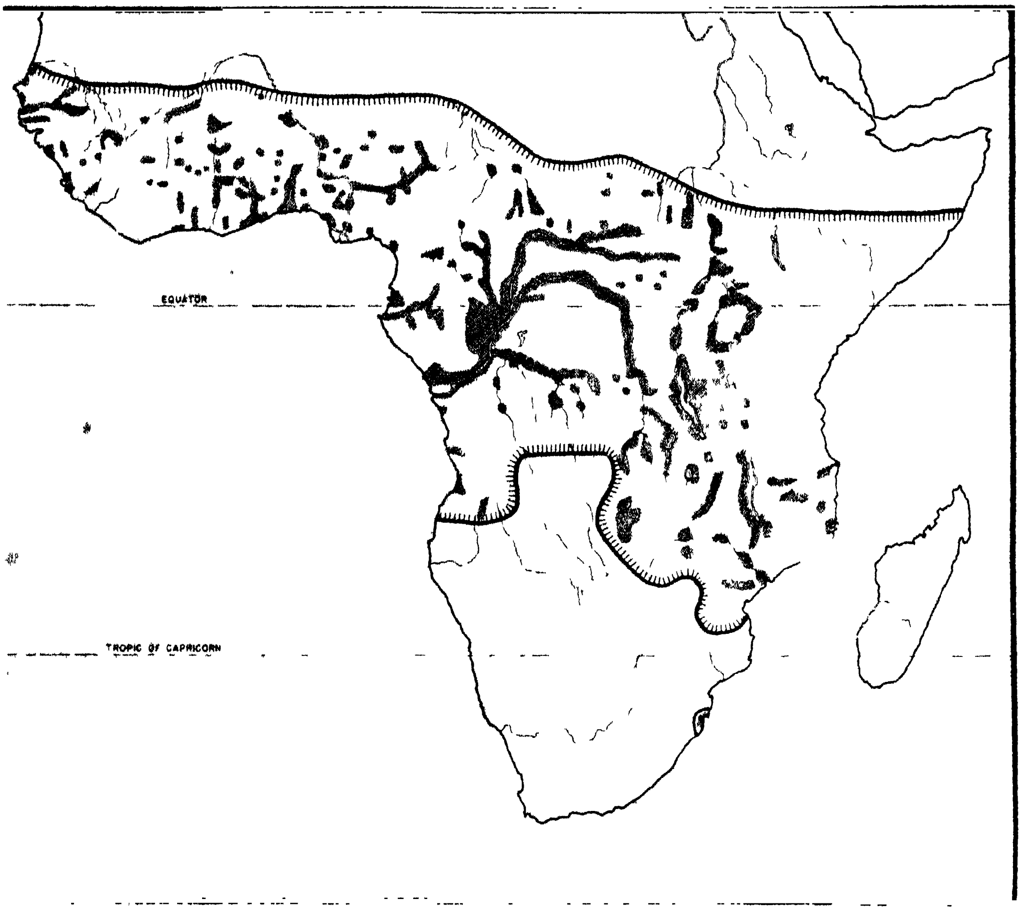
Although the virgin soil may be productive, the fertility is not such as to give large yields for an extended period of years. The rapid decline in productivity of the land is due primarily to the depletion of the humus content of the A-horizon, the decline in the amount of available nitrogen, and the accompanying speeding up of the leaching of other plant nutrients. Often there is also considerable loss through soil erosion. In native agriculture the decline is so rapid and severe that in most places lands are abandoned after two to seven years of farming. New lands are then cleared and the old ones permitted to revert to brush and jungle. This seminomadic type of tillage agriculture, often referred to as "milpa" agriculture after conditions existing in Yucatan, occurs over large areas in the tropics. In Africa particularly this system is adversely affecting soil conditions and forest conditions in many sections. Cattle are absent or scarce in many of the tropical rainy regions, and thus manure is not available. The native has little knowledge of green manures, and he usually lacks the money to buy the considerable quantities of fertilizer which would be necessary to keep up the fertility of the soil, particularly if he produces for home consumption only and not for the world market. Modern pedologic studies in the Netherlands East Indies, the Belgian Congo, and elsewhere have shown conclusively that, regardless of luxuriant stands of forest, most soils of the rainy tropics are poor rather than rich. Maintenance of soil fertility and increase in soil fertility are problems which will require a great deal of scientific study, both in regard to what is physically and what is economically possible.

In the tropical rainy regions the greatest densities of rural population frequently coincide with regions of recent volcanic activity, where decomposition of basic ash and lavas occurs rapidly, and where these volcanic materials are so young that leaching has not yet succeeded in impoverishing the soils. This is well illustrated in Java, Costa Rica, and Salvador. A still more striking example is the island of Sumatra, where population is dense on the volcanic soils in some of the highland areas, and where on the volcanic soils of Deli lies one of the major areas of modern tropical plantation industry in the world. By far the largest part of the lowland area of eastern Sumatra, however, is sparsely populated, and the soils are so poor that the area has little agricultural future.

Among other handicaps facing tropical agriculture is the prevalance of plant and animal pests and diseases. Warm, humid climates with a total absence of frost are conducive not only to an abundance of insect life, but also to the development of fungi and all sorts of microorganisms. Commercial plantations of various kinds have been ruined because of the attack of some disease against which the scientist has proved powerless. The plantations of "Arabian" coffee (*Coffea Arabica*) in Ceylon and the Netherlands East Indies were completely destroyed at the end of the nineteenth century by a fungus, *Hemileia vastatrix*, and only replacement with hardy, but less valuable *Robusta* varieties saved the industry. The cacao plantations of Ecuador are threatened with destruction by the dreaded witch broom disease. Entire districts in parts of Central America have had to abandon banana production because of the ravages of the *Sigitoka* disease. Furthermore, fungi and insects quickly attack stored products unless precautionary measures, nearly always expensive, are rigorously carried out. Many tropical products are highly perishable and must be marketed promptly to avoid deterioration; hence, long-time storage and orderly sale in response to market demands, such as characterize the marketing of grain crops in the middle latitudes, are impossible. The conditions favorable to insects and microorganisms result in a high disease rate among all kinds of livestock. In large parts of Africa the occurrence of the tsetse fly precludes the keeping of any livestock whatsoever (see Illus. p. 102). Dairy cattle such as are kept in the middle latitudes do not flourish in the rainy tropics and generally cannot be kept economically. Cattle must be resistant to disease, as are the water buffalo of southeastern Asia and the Brahma cattle of India.

Subsistence agriculture as carried on by the native peoples is primitive and mostly of the patch farming or "milpa" type. (See Illus. p. 103.) The general practice is to make a small clearing and farm it for a few years until the productivity falls so low that it must be abandoned, and then proceed to make a new clearing. Fortunately, under the stable climatic conditions, crop failures are not frequent. The population over most of the areas is relatively sparse, and the standards of living are low. Rice, roots, fruits, nuts, and game are the chief features of the diet. Fish are generally plentiful and but little other meat is needed. Where the native population is dense, as on the rich delta lands of southeastern Asia or on the volcanic lands of the East Indies, subsistence agriculture is of a much more advanced type; agricultural processes are more efficiently organized. This is especially true in the regions of "sawah" or "padi" rice agriculture. Crop rotation may be practiced, methods of tillage are better, and the use of manures is known.

Commercial agriculture in the rainy tropics is mostly of the highly organized estate or plantation type. This type is a form of large-scale agriculture, which necessitates heavy capital investment for machinery and equipment, keeps in close touch with modern scientific developments, and specializes in products for the world market, such as sugar, bananas, tea, cacao, and rubber. Under the estate system of production the enterprise usually is incorporated and the management is in the hands and under the control of people and capital from the northern climates. (See Illus. B, p. 103.)



After W. Frantzen: Matériaux pour l'étude des calamites, No 16, Geneva, 1928

Distribution of *Glossina palpalis* and *Glossina morsitans* (tsetse flies), carriers of the germs that cause sleeping sickness. In areas infested by tsetse flies it is impossible to have any domestic animals on account of the ravages of the disease.

In recent decades native agriculture in many parts of the rainy tropics is turning more and more toward production for the world market. Cacao production in many cases is essentially a small-scale native industry, as in the Gold Coast and in Brazil. A considerable portion of the rubber production of British Malaya and the Netherlands East Indies now comes from native rubber gardens. Also, the production of copra from coconuts is largely a native, and not a plantation, industry.

Plantation industry is still most successful where scientific knowledge and skill, high capital investment and careful preparation for market are necessary, such as in the case of bananas, sugar, coffee, tea, and palm oil.

Photo by N. A B.

(A) Patch farming in the tropics, near El Pato, southwest of Lake Maracaibo, Venezuela. Corn raised for human consumption. Note the tropical rainforest in the background.

Establishing the plantation. While practices differ with crops and districts, the procedures followed in establishing agricultural plantations in tropical lands show much similarity. The steps taken are usually about as follows: (1) the land is investigated carefully as to soils, slopes, drainage, forest cover, and local climatic conditions; (2) the land selected is then surveyed, and the location, size, and form of the field units are determined; (3) farm headquarters are established and the necessary construction program is inaugurated to provide water supplies, living accommodations for the white employees and native laborers, pastures for draft animals, and warehouses for materials and supplies; (4) the underbrush is cleared with machetes and small axes, and the slash is burned; (5) the large trees are felled, and some of the logs are used for timber while others are left where they fall; (6) roads are built to serve the individual farm units, and often tramways are extended into the fields to be used in hauling out the harvested products; (7) in some cases drainage ditches must be constructed, in others, ditches for irrigation, and in still other instances both drainage and irrigation must be provided to take care of heavy floods during wet seasons and droughts during dry seasons, either of which may prove disastrous to the growing crops.

The most efficient use of the lands of the humid tropics involves scientific practices of a high order. In addition to the steps outlined, it usually is necessary for the plantation owners to provide medical and hospital services, school facilities, and recreation centers. Economic welfare is de-

Courtesy United Fruit Co

(B.) Spraying the trees against disease on a modern banana plantation.

pendent upon the maintenance of a community wherein the white officials and the native labor are healthy, energetic, and cheerful. Facilities to promote such results involve expense, but general experience indicates that the outlays are economically as well as humanely sound.

The Tropical Savanna Type of Climate

(Areas marked 2 on World Map of Climatic Regions, and on Illus. p. 96.)

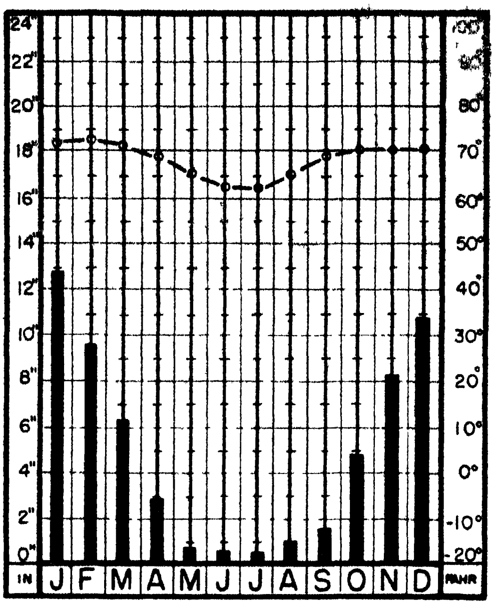
The tropical savanna type of climate has a long rainy season and a short but pronounced dry season. This distinctly seasonal distribution of rainfall is the chief difference between the savanna and the tropical rainy type, although the savanna also usually has a smaller total amount of precipitation. A difference of lesser consequence is the slightly greater seasonal temperature range resulting from the higher latitudes of the savanna areas. Toward the outer margins the dry season may become so long and pronounced that the climate is distinctly subhumid.

The map of Climates of the World, at the end of book shows that the tropical savanna climate is probably more extensive than any other. On the whole, it occurs north and south of the tropical rainy areas, extending ten or more degrees of latitude beyond them on either side, thus marking the first stage in the gradual transition from rainy to dry. The principal areas where it is well developed are the southern Sudan of Africa, parts of India and Siam, northern Australia, the Brazilian campos, the Orinoco Basin, the west coast of Central America, and southern Mexico including much of Yucatan. It will be noted that in the western hemisphere the areas of seasonal rainy climates occur mostly along the west coast and in the interior, and that much of the east coast has the all-year rainy type.

Winds. The tropical savanna type of climate extends far enough north and south of the equatorial zone to include large portions of the trade-wind belts. As already mentioned (page 64), the sun's rays strike the earth at constantly changing angles. The noonday sun is overhead at the Tropic of Capricorn on December 22, at the equator on March 21, at the Tropic of Cancer on June 21, and again at the equator about September 22. Thus, in the course of a year, all places on the globe have at least one high-sun period and one low-sun period; near the equator there are two of each, although the difference between the high- and low-sun positions is not great. At distances of 10° or more from the equator, these periods are well marked, and of course insolation is relatively great during the high-sun period and appreciably less during the low-sun period. As the sun's position moves northward and southward, pressure and wind belts follow suit. Although this shift is not great in the tropical savanna regions, which are located relatively close to the equator, it is sufficient to bring about a slight seasonal rhythm in temperature and a much more pronounced rhythm in rainfall. During the high-sun period, when the noonday sun stands practically overhead, insolation is at its maximum. The heated air expands and rises, and surface winds are weak and irregular as the trade winds recede poleward. This is the rainy season. During the low-sun or "winter" period the trade winds reassert themselves. Since they blow toward warmer regions, they give little or no rain except where intercepted by mountains. The low-sun period is therefore the season of drought.

Temperature. Temperatures in tropical savannas average above 65°F., as in the tropical rainy regions, but the seasonal range is somewhat greater. As a rule, the highest temperatures immediately precede the period of maximum rainfall. In the Sudan the hottest months are April and May. In June, when the rains are quite copious, temperatures drop. In Bengal, rains are welcomed because they are accompanied by lower temperatures and thus bring relief from the excessive heat of the preceding weeks.

Rainfall. The rainfall, although abundant, is not excessive. The annual precipitation in most savanna areas is between 30 and 60 inches. Marked seasonal concentration is the most prominent characteristic of the rainfall. While the record of Cuyaba, Brazil (see Illus. below), shows a somewhat more irregular march of temperature than do the records of Singapore and French Guiana, the greatest difference lies in the smaller rainfall total and in the existence and duration of a dry "winter" season. The length of the rainy season varies in different sections of the tropical savannas from eight to less than five months. The dry season is comparatively brief near the equator, increasing in duration poleward. During the rainy season, roads and trails are muddy, in places almost impassable. During the latter part of the dry season the ground and air are parched and dusty, wooden and leather objects shrink, and lips crack. These pronounced seasonal changes involve greater efforts at adjustment on the part of man than are necessary under a more monotonous regime of rainfall. Storage of food for people and feed for animals is necessary because the dry season is one of low productivity and resulting scarcity. The population cannot lead the hand-to-mouth existence that is typical of so many of the inhabitants of the rainy tropics.



Savanna climate Average temperature and precipitation, Cuyaba, south-central Brazil Altitude 495 feet, total precipitation 55 inches.

On the whole, because of the range of temperature and humidity, the regions of the tropical savannas escape the extreme monotony so characteristic of the tropical rainy belt, and the climate is therefore somewhat more conducive to physical and mental activity.

Tropical cyclones—storms to be feared. Parts of the savanna areas are visited by tropical cyclones, which originate over the seas but which sometimes cause great havoc on adjacent land areas. These storms develop at sea in latitudes 10° to 20° north and south of the equator and thence follow roughly semielliptical paths, first westward, then poleward and eastward. They are known in different sections by different terms. The term *hurricane* is restricted to the West Indies, the western South Pacific, and Australia. In the northwestern Pacific Ocean and the China Sea, storms of this type are called *typhoons;* in the Indian Ocean, *cyclones.*

While the atmospheric disturbance created by the tropical cyclones may extend over large areas, the really dangerous and destructive center generally has a diameter of less than 200 miles. Tropical cyclones usually lose their violent energy soon after striking continental land masses, and therefore they generally bring heavy downpours rather than high winds to interior points. On the islands and along the coasts the destructive effects upon crops and buildings are often appalling. Wind velocities exceeding 100 miles an hour are frequently experienced; with such winds, crops are ruined, trees uprooted, and buildings blown down. This hazard is one of the most serious handicaps to agriculture within the areas subject to these tropical storms.

Native vegetation. The native vegetation in regions of tropical savanna varies from deciduous forest to grass The most widespread type is the savanna—a grassland mantled with tall, coarse grasses, and dotted with clumps of deciduous trees. In some areas, the trees occupy such a large percentage of the uplands that grass is not abundant, elsewhere, only scattered trees or clumps of trees break the monotony of the grassy plain, while along the courses of major streams there may be dense jungle (See Illus. above) This is the type of landscape that exists over large areas in the southern Sudan and that forms the so-called Campo Cerrado of Brazil The marked dry season causes general leaf fall and cessation of growth on the part of all broad-leaved trees. Since there is somewhat greater similarity of conditions and of products to those of the higher latitudes, these climatic regions do not furnish such a large variety of products for the American and European trade as are furnished by the tropical rainy regions

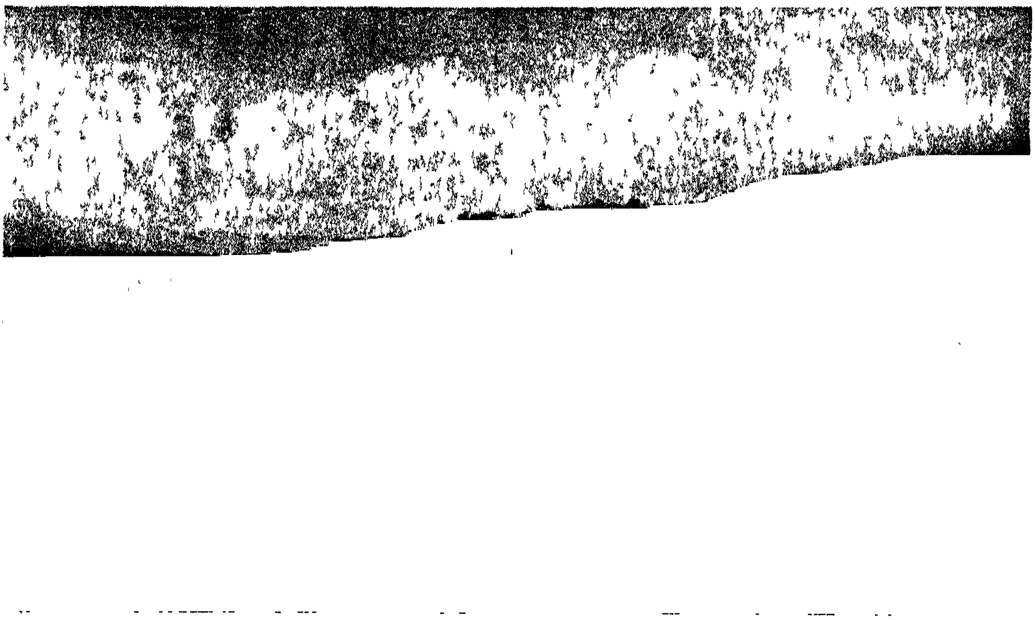


Photo by N A B

Short-grass savannas in northern Maracaibo Basin, Venezuela Scattered deciduous trees on slopelands

Native fauna. Since tropical savannas have an abundance of trees and grass, of water and sunshine, of herbs, roots, nuts, and fruits, it follows naturally that animal life also should be abundant. Within these regions are the lands of big game in Africa and similar areas of varied wild life in South and Central America In its more humid phases this type of climate in Africa harbors the elephant, hippopotamus, rhinoceros, and zebra, while the giraffe, warthog, and other animals that are fleet of foot inhabit the drier sections In the jungle areas within the savannas are found the tiger and cougar, while in the tall-grass savanna the lion is the king of beasts In general, the animals of the well-wooded and tall-grass savannas are large and well fed The numerous varieties include arboreal, aquatic, and ground types, not any one of them strongly predominant On the whole, they are less arboreal than those of the jungle and rain forest, and also less fleet-footed than those of the dry savannas They include species larger and stronger than their neighbors of either the humid or the semiarid bordering regions.

Soils. The tropical savanna soils are yellow or reddish, usually more deeply colored than those of the tropical forest lands. These soils are subjected to an annual season of desiccation such as the rainy tropics lack. The tropical red and yellow soils belong to the group of lateritic soils, and as such they are weak in humus and soluble mineral plant foods. Since they have developed in regions where rainfall is not so heavy, the savanna soils are not so thoroughly leached as the soils of the rainy tropics, and they have a somewhat better physical structure and a less compact subsoil. After the land is cleared, the soils are ordinarily quite productive for a few years, but they quickly deteriorate unless manure or fertilizers are applied.

Since the tropical savannas constitute a transition zone from humid to semiarid lands, there is a similar transition in soil characteristics. The soils of the rainy equatorward areas are lateritic; they are more thoroughly leached than the soils of the drier and somewhat cooler areas that lie farther from the rainy belt. Since the latter are subject to less leaching, the content of soluble salts is higher, the color tends more toward gray than red, and the subsoil is more friable. In general, the soils of the drier parts of the savanna are more fertile than are those of the rainier areas, and they are more easily tilled. As elsewhere, the alluvial lands along streams or along mountain fronts are generally fertile because their soils are the result of deposition of the richest detritus washed down from higher, weathered slopes.

Agriculture. The savanna climate is favorable for agriculture. Its capacity to sustain population is well shown in India and parts of Africa. Population maps reveal extensive areas of moderate to dense population where this climate prevails, in contrast to the few areas of density in the rainy equatorial belt. Although the areas of dense population within this climatic type in southeastern Asia are not entirely comparable with similar areas in Africa and South America, they do indicate some interesting possibilities for these latter regions when pressure of the rapidly increasing world population may provide sufficient incentive to overcome the natural drawbacks of the savanna.

Areas of this type of climate have a number of distinct advantages. The dry season gives man more energy than does a continuously humid climate. Clearing the land is easier, since the forest stand, if any, is less dense. The young trees, the dead grass, and the slash from clearing bush and trees can easily be burned during the dry season, and the ground can be plowed and planted at the beginning of the wet season. Some types of grasses and grains can be produced advantageously. The rainy season is the growing season. The dry season is harvest time, when the dry air favors complete ripening and hardening of the grain, thus rendering the stored products less subject to attack by fungi or insects. The grains typical of these regions are many kinds of sorghum and millet, corn, and, where irrigation is possible, rice. Sugar cane is a staple crop for local sugar production, and in some places cane sugar takes high rank as an export commodity as well. Cotton is grown for local clothing material, and its cultivation has important commercial possibilities. The inedible character of much of the wild grass, and, in Africa, the tsetse fly, have hampered cattle-raising. On the whole, the savanna lands have a better developed agriculture than the rainy tropics, particularly the agriculture of the farmer type in contrast to the plantation system so important in the all-year wet and warm regions.

The Tropical Highland Type of Climate

(Areas marked 3 on World Map of Climatic Regions and on Illus. p. 96.)

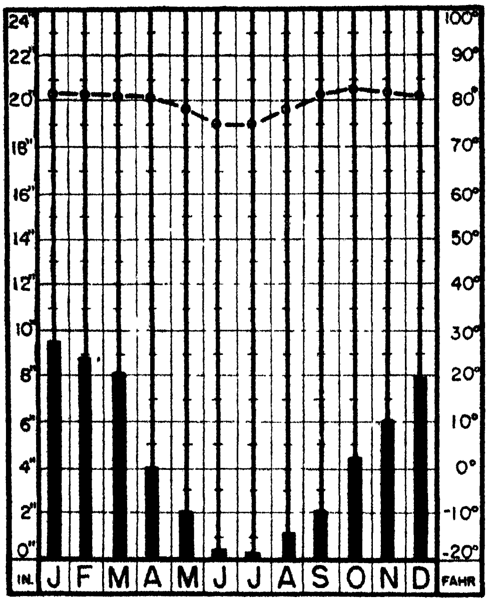
The tropical highlands differ from the lowlands in having lower average annual temperatures and greater daily range of temperature. Because of the small number of stations with long weather records located within the tropical highlands, the regions as shown on the map at end of book have been delineated on the two-fold bases of available climatological data and elevation above sea level. The areas of tropical highland type of climate lie mostly at altitudes between 2,000 and 6,000 feet above sea level, but there are some notable exceptions where greater heights are reached, as in Ethiopia and southern Mexico.

The largest area is in Africa, extending from Lake Victoria southward and westward across the headwater districts of the Congo and Zambesi rivers; smaller areas include Ethiopia and the highlands of southern Africa and of Madagascar. Important areas outside of Africa occur in southern Arabia, southern Brazil, and southern Mexico (see World Map of Climatic Regions at end of book).

Essential characteristics. Cooler temperature in comparison with the adjacent lowlands is the outstanding feature of the tropical highland type of climate. The average annual temperatures vary from about 65° to 72°F., and the difference between the mean temperatures of the warmest and coldest months of the year is commonly less than 10°. The warmest months are of course associated with the high-sun seasons, the temperatures then averaging from 68° to 78°F. The coldest months occur during the low-sun periods, with averages from 45° to 65°F. (Illus. right, representative of the tropical highland climate of Brazil). The difference between daytime and night temperatures is fairly pronounced. Warm to hot days and clear, cool nights are typical; frosts are rare but may occur at the highest altitudes.

Rainfall is usually ample but varies greatly in different regions, some regions having only about 30 inches per year whereas certain others receive up to 80 inches and more; 40 to 60 inches can be considered a fair average. Periodicity of rainfall is pronounced everywhere. The rainy season occurs during the high-sun period of the year, the dry season during the low-sun period. For areas south of the equator, July is usually the driest month, while the rainy season lasts from October to April, the rainiest month occurring within that period but varying locally. North of the equator opposite conditions prevail.

The trades are the dominant winds, and they serve the doubly useful purpose of bringing in moisture and rendering living conditions more pleasant through their steady breezes. On the whole, climatic conditions are quite favorable for human activities, a fact attested by the progressive people who inhabit the highlands of eastern Brazil and southern Mexico.



Tropical highland climate. Average temperature and precipitation, Bello Horizonte, north of Rio de Janeiro, Brazil. Altitude 2,571 feet, total precipitation 59 inches.

Native flora. The native vegetation varies from forest to short grass and scrubby bush, chiefly in accordance with differences in rainfall. The rainfall, although fairly heavy, is not sufficiently well distributed to support dense forest except in some favored localities. In general, scattered tree growth, low, thorny scrub, and grass prevail, as for example in Africa east and south of Lake Victoria. In Angola and northern Rhodesia there are open forests with trees thirty or more feet high, yet not dense enough to suppress a grass cover. Some kinds of trees form nearly pure stands, but usually the trunks are crooked and twisted. In other regions there are areas where tree growth is so sparse that the problem of obtaining wood for cooking purposes is a handicap to settlement. The high slopes are usually forested, and the higher parts of the plateaus are favored with a grass cover wherever the tree stand is fairly open, as on the Abyssinian Plateau and the mountain slopelands above the Valley of Mexico.

The growth of grass, trees, and shrubs bespeaks the prevalent fertility of the soil of these areas. This growth is due in no small measure to the moderate amount of rainfall and to its seasonal distribution, both factors tending to conserve the soil and its soluble elements.

Soils. The upland soils of the tropical highlands are partly red and yellow soils similar to those of the rainier sections of the savanna lands; others have some characteristics similar to those of the black soils of temperate lands, especially where rainfall is low and a grass vegetation prevails. This dark soil is usually very fertile.

As the altitudes are greater, valleys have been eroded deeply in most areas, and the topography is much more rugged than that of lower lands. As a result of the more active erosion, the soils are younger and are more directly related to the bedrock from which they were derived. Fully developed, mature soils are not common in rugged uplands, and thus the lateritic characteristics are not so pronounced.

Many of the soils of the tropical highlands are derived from igneous rocks. The mineral salts are released by weathering under warm and humid conditions. Where the bedrock consists of basic rocks, such as lavas and intrusives, the resulting soil is reddish in color and relatively fertile. Soils developed from acidic rocks are usually less richly colored and not so productive. It is a noteworthy fact that the most extensive and successful coffee plantations supplying most of the world's commercial coffee are located on the reddish soils of tropical highlands as in Brazil.

On the whole, the soils of the tropical highlands resemble those of the savannas but are generally less leached, more readily tilled, and more productive. The application of commercial fertilizers is necessary except where active weathering furnishes the soluble minerals essential for plant growth.

Agriculture and white settlement. The tropical highlands are, on the whole, rather pleasant places in which to live. Temperatures are moderate and characterized by a diurnal rhythm which does much to relieve the monotony of small seasonal changes. Nights are usually cool enough to be invigorating. The winds are just strong enough to give a desirable freshness to the atmosphere. The rainfall, commonly 30 to 60 inches per year, is sufficient for abundant plant growth, and its seasonal distribution is conducive to well-defined periods of tilling the land and harvesting the crops.

Both grain and cattle production are actively carried on in many areas, and further expansion seems assured. Corn is quite generally grown, sorghums and millets are important in Africa, and the production of wheat and barley is common. The cattle industry on the highlands of Africa and Brazil has met with conspicuous success, although some places are so remote from markets that only the hides have commercial value. Thus, agriculture resembles that of the middle latitudes because of the altitude of the tropical highlands. As a result, these areas are perhaps the best "white man's lands" in the warm zone, but they are handicapped economically by poor transportation. The one outstanding exception to this general statement is coffee production, and for this reason the tropical highlands are sometimes spoken of as the world's coffee lands.

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Chapter Eight

AGRICULTURAL PRODUCTS OF THE HUMID TROPICAL REGIONS

For many centuries the humid tropical regions were of importance to the western world as sources of luxury articles, among which spices ranked high. When ships were small and traffic on land and sea was slow and hazardous, only products of small bulk, high value, and excellent keeping quality could stand the high cost of transportation and the long delays.

Modern large-scale commercial agriculture in the humid tropics became possible during the past century when steamships developed for ocean traffic. Now these regions supply many vital raw materials and foodstuffs to the industrialized regions of the temperate zones. In turn, the tropical lands depend largely upon the middle latitudes for the products of modern industry. Tropical countries are at present predominantly agrarian in character. The retarded industrial development in some cases is due to insufficient power and metallic resources, in some to insufficient technical knowledge, while in others it may be attributed to political dependence upon highly industrialized mother countries. In many parts of the tropics industries such as the manufacture of sugar in Java and Cuba are associated primarily with the products of the soil. However, in some parts of the humid tropics modern industry is beginning to attain considerable importance. In India the Bombay and Madras districts have become major textile-manufacturing centers, and the iron and steel industry of the Bihar-Bengal region is rapidly growing in importance. Brazil is building up important industries in the state of Sao Paulo and the Rio de Janeiro region, especially the cotton textile industry. It can be expected that in the future other modern industrial regions will develop, especially where water or other power and raw materials are available, and where suitable labor can be found, thus lessening the dependence of the humid tropics upon agriculture.

Among the many products of the tropical regions, bananas, cacao, coconuts, and rubber are typical for the areas of rainy tropical climate. Of somewhat less prominence in these regions are spices, medicinal materials, and cabinet woods. Sugar cane is grown in both the rainy tropics and the regions with a savanna climate, while coffee is produced in areas of tropical highland climate.

Most of the products characteristic of the tropics cannot be grown commercially elsewhere because of their need for high temperatures at all seasons. This is particularly true of bananas, cacao, and coconuts. Some others, like sugar, are not limited to the tropics, but yields are likely to be lower, and therefore costs of production materially higher, when grown outside the areas of optimum natural conditions.

During the past half century the humid tropics have become an integral part of world economy, and in the future, as the population of the earth grows, they are bound to play a role of increasing importance as purveyors of foodstuffs and raw materials for the areas of dense population farther poleward. Even now, events, such as war, which seriously impede the exchange of products between the lower and the middle latitudes have serious economic consequences. The great shortage of fats in Europe during both world wars illustrated the fact that western Europe has come to rely to an increasing degree upon imported vegetable fats from the tropics.

As has been mentioned in the preceding chapter, while much of the agriculture of the tropical areas is still of the subsistence type, during the last half century the plantation or estate type has greatly increased in importance. In many parts of the tropics native production also is becoming more and more oriented toward export crops and world markets, or markets of the mother countries in the case of certain colonial regions.

Modern banana production is an excellent example of large-scale plantation or estate-type tropical agriculture, cacao is a typical crop of native commercial agriculture, while production of tropical vegetable oils and rubber is in the hands of plantations and native growers.

The Banana

The banana has long been a staple food of the people in the humid tropics. In the United States, the sweet banana is so common on the fruit stands as to lead people to believe that it is the only kind grown, they are surprised, therefore, to learn that in the tropics there are hundreds of varieties, differing greatly in size, color, flavor, and uses. Some bananas are large, others small; some are red, others light tan to deep yellow; some are sweet and edible when ripe, while others are starchy and must be cooked or roasted before they can be eaten. Still others, like *Musa textilis,* the source of Manila hemp, are valuable for the fibers of their leaf stalks. (See Illus. below.)

The large number of varieties makes the banana of paramount importance in the subsistence agriculture of the tropics. The plant furnishes both food and materials for shelter and even for some forms of clothing adapted to tropical conditions.

Photo by N. A B

View of the platano or plantain. The platano is a starchy banana that is eaten cooked or fried. Its role in the diet is somewhat similar to that of the potato in higher latitudes.

Climate and soil conditions. Bananas require all-year warmth and abundant moisture and sunshine. They will endure temperatures as low as 48°F., but the optimum is much higher, about 75° to 85°F. The plant makes enormous demands for water, and therefore is most successfully grown where a rainfall of 80 to 200 inches is well distributed throughout the year. In certain areas where rainfall is deficient during part of the year, but where water supplies are available, production under irrigation is proving quite successful, particularly since in such areas the dreaded Sigitoka fungus disease has not as yet appeared. This is true especially along the west coast of Central America.

Wind is another important factor. While the plant can stand fairly strong winds during its growing period, a blow of 20 miles an hour may prove disastrous when the fruit is maturing. Finally, bananas require fertile, friable, well-aerated soils. From these requirements it is clear that the banana, though produced throughout the tropics, generally finds optimum conditions for large-scale commercial production in the areas with a rainy tropical climate.

Courtesy United Fruit Company.

A bunch of bananas nearing maturity. Note that the individual bananas, the "fingers," point upward from the stem.

Principal commercial species of bananas. From a commercial standpoint, the most important species of banana is *Musa sapientum.* The species presumably was native in the tropical lands of the Far East but was brought early to the Western Hemisphere and is now found growing in the humid lowlands throughout the rainy tropics. The principal variety is known as *Gros Michel,* the fruit of which is large, well flavored, and capable of standing shipment —qualities which give it commercial leadership. A less popular variety is the red banana, known also as *Baracoa* and *Red Jamaica.* The fruit is shorter and stubbier than that of the *Gros Michel,* and the bunches are smaller.

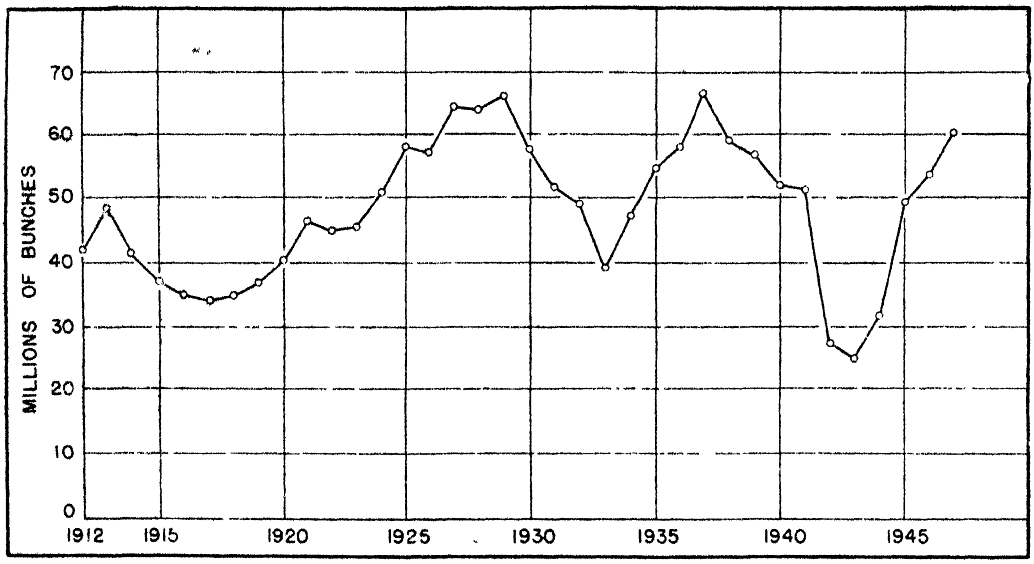
Another species of the same family is the *Musa paradisiaca*—Fruit of Paradise—more commonly called the plantain or platano. It is in common use in the tropics as a starch food, like our potato, but does not enter into world trade. (Illus. p. 112.)

Localization and international trade. Major commercial production centers in the lands around the Caribbean—near the greatest consumer of bananas, the United States (see frontis., Physical Map of the World)—such as Honduras, Guatemala, Colombia, Costa Rica, Panama, Mexico, Haiti, Jamaica, Nicaragua, and Ecuador. Other important exporters are Brazil, the Canary Islands, French West Africa, the Cameroons (now partly in Nigeria, partly in French Equatorial Africa), and Formosa. (See Illus. p. 115.)

Because of the perishable nature of the banana, large foreign shipments became possible only after modern, fast methods of transportation were developed, with specially built steamships, loading and unloading equipment, warehouses, and railroad cars.

Local production by unsupervised natives failed to provide a supply of fruit dependable both as to quantity and quality, and it soon became evident to leaders in the commercial banana industry that success could be attained only through co-ordination of production, harvesting, transportation, and marketing processes. At the turn of the century, great corporations were organized on that basis, and since then the industry has become a huge, integrated business involving complete co-ordination of all processes from the planting of the "bit" in the tropical lowland to the delivery of the ripened fruit to the retailers in American and European cities.

The banana plantation. The long growing period before harvest, and the expenses of cultivation in the meantime, add to the large-scale capitalistic character of the commercial banana industry. In most regions, profitable returns are not expected within two or three years after planting.

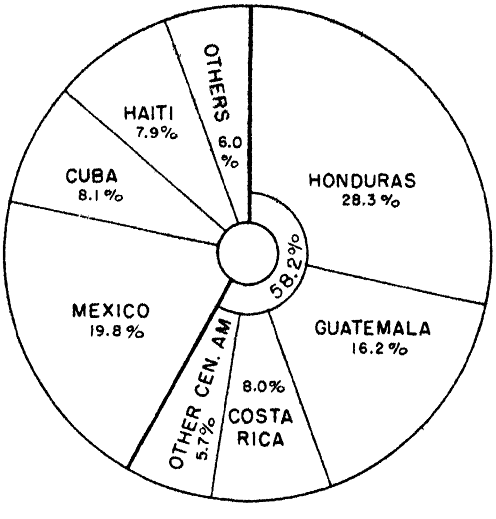


Annual banana imports of the United States

The banana is propagated from rhizomes and suckers. Plantations are first set with pieces of rhizome or rootstock, called *bits*, selected from vigorous, healthy plants. During the growth of the plants, *cleaning* must be done three to five times a year. This consists of cutting away with a machete the ever-luxuriant weeds and undergrowth.

A period of 11 to 14 months is necessary for the banana tree to attain maturity and develop its blossom, at which time it reaches a height of 16 to 30 feet, depending on soil and weather conditions. Three or four more months are necessary for the development of the fruit to the point where it is ready for cutting. It is thus from 14 to 18 months after planting before the first crop is ready, and that crop is usually of little value because the root systems have not developed sufficiently to produce the full-sized bunches of large, plump fruit demanded by the trade. (See Illus. p. 113.) While the mother plant is maturing its bunch of fruit, young sprouts known as *suckers* make their appearance. Soon after the bunch of bananas has been gathered, the stem of the plant is cut down, for each tree bears but one bunch or stem of fruit. The suckers are then removed from the inner side of the basal stem, only a limited number being allowed to develop along the outer edge. These suckers bear the first profitable crop. After that, production is virtually continuous during the life of the plantation, a period varying in different regions from 5 to 15 years, or even longer. As the plantation ages, the original single plant becomes succeeded by a sort of circular hill or *mat*.

Harvesting and marketing. The harvesting and marketing processes, as operated by the major fruit companies, approach perfection in co-ordination of industrial technique. As the incoming ship approaches the port, radio instructions are sent from company headquarters to the local managers notifying them as to the number of stems desired, the exact hours for loading, and the destination of the cargo. The local managers then instruct the superintendents of the banana farms by telephone as to the number of stems each is to supply and for what market the cargo is destined. The probable number of days that will elapse from the day of cutting until the fruit reaches consumption centers is estimated; cutters are advised accordingly, and orders are issued timing the work so that the fruit is delivered and the cars loaded at the railroad sidings but an hour or two before the engine comes along to make up its train for the trip to the port. The railroad trip may be 10 miles or it may be 60, but the work is so integrated that the loading of the 40- to 80-thousand-stem cargo is accomplished in 8 to 12 hours without congestion or confusion. The clocklike precision with which these processes of harvesting and transportation are carried on is necessitated by the climatic conditions and the perishable nature of the fruit.



Countries of origin of bananas imported by the United States

Cacao

Cacao is one of the crops most typical of the areas of rainy tropical climate. The cacao tree (*Theobroma cacao; Theobroma* = food of the Gods) is a native of the American tropics, and its cultivation has spread to tropical parts of other continents. The tree is restricted to tropical lowland areas, for it requires an average temperature of at least 75°F. and a minimum temperature that does not fall below 60°F. Humidity ranging between 80 and 90, and rainfall of 50 inches or more per year, are essential. Commercial success is not possible where there is a marked dry season. In many regions it has been found advantageous to provide shade by interplanting other, taller trees, referred to as *madre de cacao* (or cacao mother) in Latin America, in order to prevent excessive evaporation.

The damp, warm climate required for commercial production of cacao, unfortunately, favors plant diseases, and cacao has probably suffered from these more than has any other commercial crop of the tropics.

Cacao production. The cacao tree blooms continuously, and always carries some ripe fruit. Usually, however, there are one or two principal harvests during the year. The fruit is a pod containing a number of seeds, the cacao beans. The beans are shelled from the pod, are subjected to a fermentation process and dried, and then are ready for shipment. The processes of preparing cacao for market, therefore, are essentially simple and do not require costly equipment. Once the beans are prepared, they keep well and no special transportation facilities are needed. Thus cacao does not need to be grown on large plantations but can be produced in satisfactory qualities by small, native farmers. (See Illus. p. 116.)

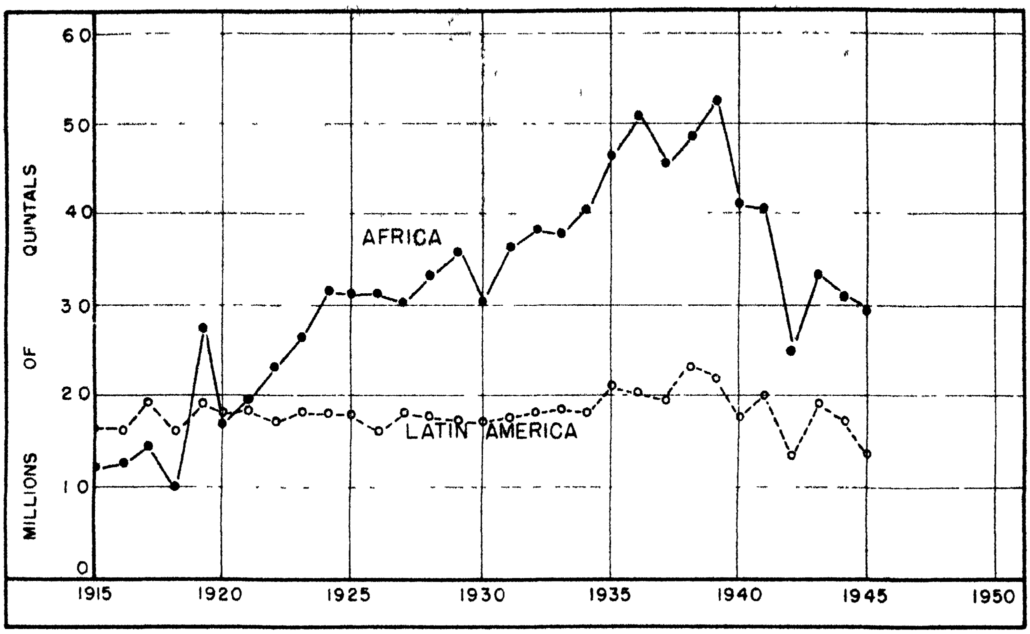
In preparation for consumption the beans are cleaned, dried, and roasted. Chocolate is produced by adding some sugar to the finely ground beans. Cocoa is made by removing most of the vegetable fat, the so-called cocoa butter, which is in great

(A) Picking cacao pods on a plantation in Ecuador Note pods attached to trunks of trees Women in foreground are shelling the cacao beans from the pods

(B) Drying cacao beans in the Rio Guayas valley in Ecuador.

demand for the preparation of cosmetics. The rapid increase in consumption of cacao during recent decades is due to the production of cheaper sugar and a general rise in the standards of living.

Distribution. Most of the cacao that enters world trade is derived from two types of cacao, the *Criollo* and the *Forastero*. The Criollo type, planted principally in America, furnishes a cacao of superior grade, in great demand for blending purposes, but the tree gives rather low yields and shows little resistance against disease. The bulk of the world's cacao, including the African crop, is produced by the Forastero type. The trees are hardy and yield well, but their product has an aroma decidedly inferior to that of the Criollo.



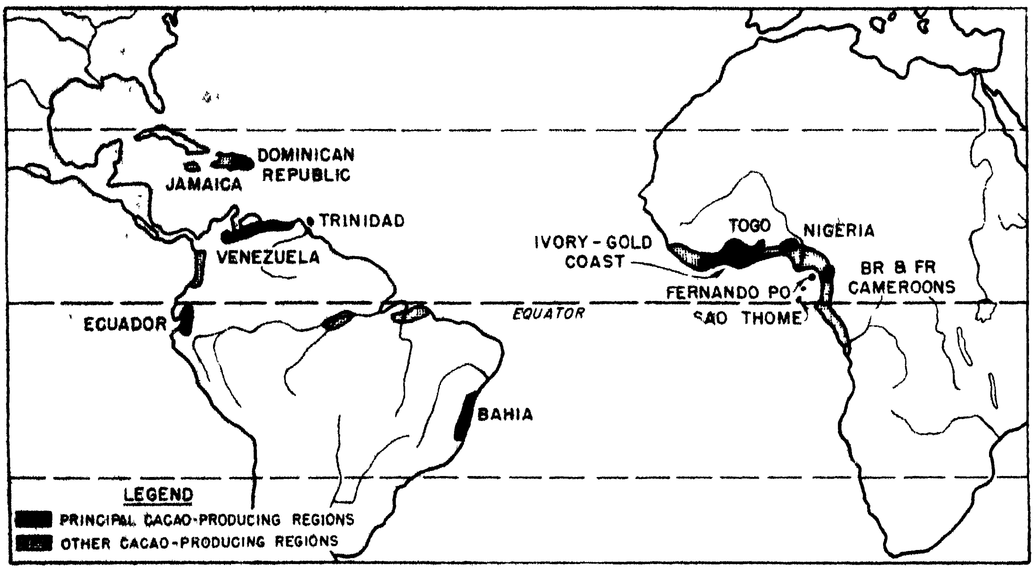
Annual exports of cacao from Africa and Latin America since 1915.

Tropical South America, especially Ecuador, and the West Indies were for centuries the world's main source of cacao. In the latter part of the nineteenth century a new area of production began to develop in Africa, first on the islands in the Gulf of Guinea, and later on the Guinea coast itself. By 1920 this area had definitely outstripped the old centers of production in the Western Hemisphere. (See Illus. below and p. 118.)

About two-fifths of the world's cacao crop comes from the Gold Coast, in Africa. Other portions of the tropical rain-forest belt that skirts the Gulf of Guinea also produce cacao. Along the coast of Nigeria the cacao industry is steadily increasing in importance, and sufficient land is available for considerable expansion. The French have established an important cacao industry in the Ivory Coast, the bulk of the output being shipped to France. Producers of lesser importance are Spanish Guinea, Togoland; Saint Thomas and Principe islands, selling their cacao through Lisbon; and the Belgian Congo, exporting chiefly to Spain. In Africa, the cacao plantations are mostly in the hands of the natives, with only a minor percentage of European estates.

In America the principal centers of production are much more scattered. The newest and at the same time the most important producer is the state of Bahia, which makes Brazil second only to the

Gold Coast in world output. The cacao is grown on the river flats and lower hills of the coastal strip, where temperatures are high and where the southeast trade winds provide abundant precipitation. Brazilian cacao is comparable in quality with that from the Gold Coast and brings only slightly higher prices. Another important producer of ordinary cacao is the Dominican Republic.



Principal cacao producing regions of the world

Superior grades of cacao are exported by Trinidad, Venezuela, and Ecuador. In Venezuela the majority of the cacao plantations are located in the narrow coastal strip east of Puerto Cabello and in the region around the southern end of Lake Maracaibo. In Ecuador the industry centers in the valleys north of Guayaquil. Ecuador once was the world's principal cacao producer. With the expansion in other areas the country lost its predominance, and since 1922 the advent of witches' broom, one of the most dreaded cacao diseases, for a time threatened to annihilate the industry. Other producers of some importance are Colombia, Costa Rica, Granada, and Panama.

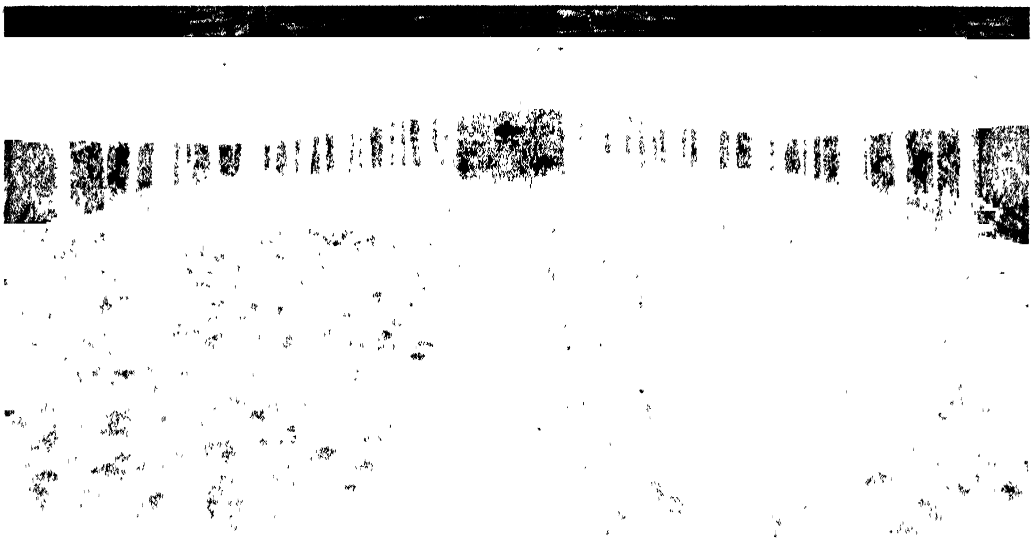
International trade. Europe and North America account for most of the world's cacao imports, the United States alone taking nearly two-fifths of the total. More than half of our imports of cacao beans come from Africa; most of the rest originate in Latin America, especially Brazil. The chief competitors of the United States in the purchasing market are the United Kingdom, Germany, the Netherlands, France, Belgium, Italy, and Switzerland. The Netherlands have a highly developed cacao industry and export considerable quantities of cocoa, cocoa butter, and chocolate. Switzerland is known as an exporter of chocolate and chocolate products.

Tropical Vegetable Oils

Fats are an indispensable part of the human diet, and many kinds of fats and oils are necessary for a multitude of modern industrial processes. In some parts of the world climatic conditions are such that it is either impossible or impractical to produce animal fats. In regions of dense population the production of animal fats is relatively expensive, and with the continued increase in the population of the world, the shortage of animal fats is becoming ever greater. In world trade the importance of vegetable fats is already far greater than that of animal fats, and the world production of vegetable fats is increasing at a rapid rate. Particularly, the densely populated countries of Europe have been looking more and more to the tropics as an important source area for vegetable fats. Coconut palms, oil palms, sesame, and peanuts are the principal oil crops which are produced successfully in the tropics, and there are a large number of other crops that hold great promise for the future.

The coconut palm. The coconut palm is one of the plants indispensable to primitive native economy in many parts of the warm humid regions. Its products are so diversified that a small grove suffices to assure tropical man of all he needs for survival: food and drink, implements, shelter, and a little clothing. During recent decades, however, the importance of the coconut palm has extended far beyond the tropical lands; its fruit has become one of the principal sources of vegetable oils for the inhabitants of the industrialized temperate regions, and for the manufacture of soap and margarine.

The coconut palm (*Cocos nucifera*) is a true child of the tropics: it requires much sunshine and continuous warmth. (See Illus. below.) Although it can stand brief periods of temperatures as low as 60°F., it does not thrive where average annual temperatures are below 75°F. High humidity and high annual precipitation, preferably over 80 inches per year, are essential; periods of drought have an unfavorable influence both on the palm itself and on its production of nuts. While the outermost limits of its distribution lie between 26°N. latitude and 22°S. latitude, the areas with climates favorable for commercial production do not reach much farther than about 20° on either side of the equator.



Courtesy Departement van Landbouw, Netherland India

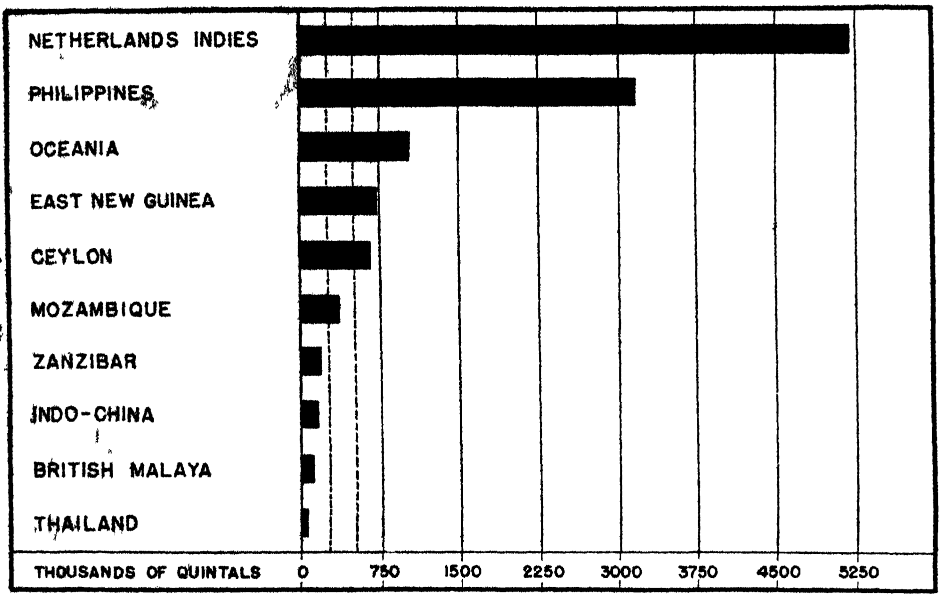
A coconut nursery. Coconuts are imbedded in moist sand. Note young sprouts growing through the husks

There is a native saying that the coconut palm needs the sound of the human voice to thrive. One might add that it also needs the voice of the sea: it is an inhabitant of the coasts of the tropics. It grows on the little atolls of the Pacific, which appear to rise out of the ocean as groves of palm trees; it fringes nearly all the shores of the islands and mainlands within the low latitudes. The coconut palm begins to bear fruit from 8 to 10 years after planting, often reaches a height of more than 80 feet, and may live to be a hundred years old. The fruit consists of an outer fibrous cover enclosing a hard, woody nut lined with "meat." This meat is valuable commercially because of its high content of vegetable oil. Not only is this oil an excellent soap stock, but its chemical composition is so closely akin to that of butter that, after being refined, it can be made into high-quality oleomargarine.

Commercial production. After the fruit is gathered, the outer husk is removed and the nut split open. Then it is dried in the sun, over a fire, or, in a few cases, with the aid of modern drying apparatus. As a result of this process the meat loosens from the hard shell. The dry meat, *copra,* contains 50 to 60 per cent of oil and thus is a relatively concentrated commodity. Sometimes the extraction of the oil takes place in or near the areas of production, but much copra still is shipped long distances to the consumer countries in the middle latitudes.

In all producing areas the coconut industry is primarily a native industry; little western capital has been invested in production. In part, this is because copra is essentially a raw material where quality does not count heavily. Furthermore, the growing of coconut palms does not require a knowledge of specialized agriculture. Its growth is thus an ideal economic activity for the natives, who can sell their copra when prices are favorable or can wholly or partially withdraw from the market when prices are low.

The centers of commercial coconut production are the Netherlands Indies, the Philippines, the islands of the western Pacific (especially New Guinea and the Fiji and Solomon islands), Ceylon, and Mozambique (see Illus. above). In the Philippines the industry is concentrated in the eastern and southeastern sections of the islands, where rainfall is high and where



Exports of copra by the principal producing countries of the world Average 1936-1939. Data for Oceania, East New Guinea, and Thailand. average for 1936, 1937, and 1938 only Postwar data are incomplete there is no prolonged dry season. The Philippine industry is strongly dependent upon the American market. Large quantities of copra and coconut oil are shipped to the Pacific ports of the United States, especially to Berkeley, California, where an important oil-crushing industry exists. Smaller quantities are sent directly to Atlantic ports. An important oil-crushing industry has developed in Manila, the only center in any of the producing areas where the oil is extracted on a large-scale basis. Because of the favorable economic and political connections, the oil normally is exported directly to the United States.

In the Netherlands Indies the commercial coconut industry is most important in the sparsely populated Outer Provinces, especially in Celebes, Western Borneo, Sumatra, and the Moluccas. The exports are sent mostly to European markets.

The principal consumers of copra and coconut oil are western Europe and the United States. In this country most of the oil is used for various technical purposes, such as the manufacture of soap. In Europe, on the other hand, much of it goes into the manufacture of oleomargarine, the cheap butter substitute of the densely populated, highly industrialized countries. Dried, shredded coconut meat is used in confections and pastries.

The only other coconut product of commercial value is the fiber of the outer husk, known as *coir*. It is used in the Orient for the manufacture of rope and other cordage, and it serves in Europe for the manufacture of coarse but strong matting. It is used in small quantities in the United States for the manufacture of doormats.

Whole coconuts are not of great importance in international trade because they are too bulky and of too low value to stand long-distance transportation. In the United States the whole nuts come mainly from the near-by Caribbean lands.

Oil palm. The African oil palm (*Elaeis guineensis*) is a competitor of the coconut in the markets for vegetable oils in the middle latitudes. Like the coconut palm, the tree requires a rainy tropical climate. It needs high humidity and a rainfall of over 80 inches and cannot stand a prolonged dry season.

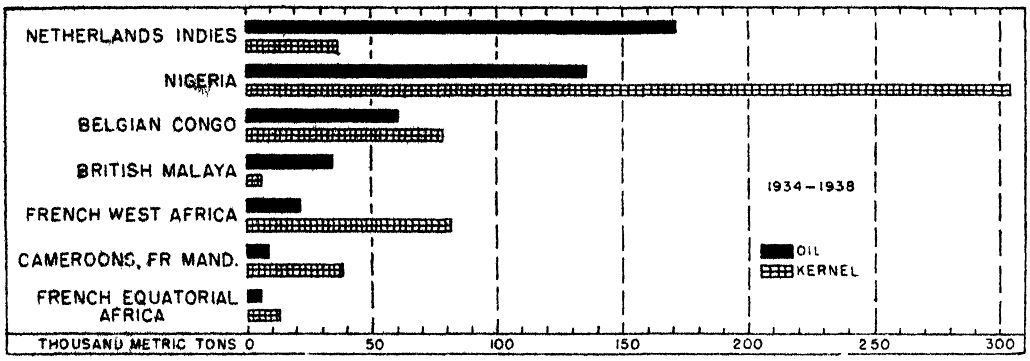
In Africa the trees are found scattered through the humid forests of the Guinea Coast and the Congo basin, and from time immemorial they have furnished the Negro with a food and an unguent. In clearing the jungle the natives have generally left the oil palms standing. Protected by the Negro farmer, these palms have multiplied until in many regions they have developed into solid groves. Oil-palm forests are especially extensive in the moist coastal lands of Nigeria and Dahomey, and a belt in which they are common stretches westward along the entire Guinea coast as far as the French colony of Senegal. Toward the south, oil palms are plentiful in the Cameroons, the Congo, and Angola.

Courtesy Official Netherlands Information Bureau in U S A

Harvesting fruit of the oil-palm. The fruit, which hangs in bunches, is rich in oil. Immediately after being harvested it is crushed, and produces palm grease and palm oil.

The fruit of the oil palm is small, from one to two inches in diameter, yellowish white, and grows in bunches which may contain as many as 1,000 to 1,500 each. It consists of a soft yellow pericarp and a hard kernel, of which the former contains the palm oil proper, the latter, the palm kernel oil. (See Illus. p. 121.)

The oil is pressed from the pericarp with the aid of primitive native equipment, often simply by means of treading. While much of the oil is used locally, a large surplus is available for export. The hard kernels keep well, contain about 45 per cent of oil and are shipped mostly to northern countries. Principal shippers of oil and kernels are Nigeria, Belgian Congo, French West Africa, especially Dahomey, the Cameroons, Angola, Togo, Sierra Leone, Sao Thome, and Principe. (See Illus. above.)



Exports of palm oil and palm kernels from major producing countries. Average 1934-1938. Postwar data are still incomplete.

In Africa, the processes of oil production are primitive and transportation often is slow and difficult. Much of the oil so produced is of such low quality that it can be used only for ordinary soap stock. Yet, Nigeria and Sierra Leone depend almost entirely on the exports of oil and kernels for their revenues.

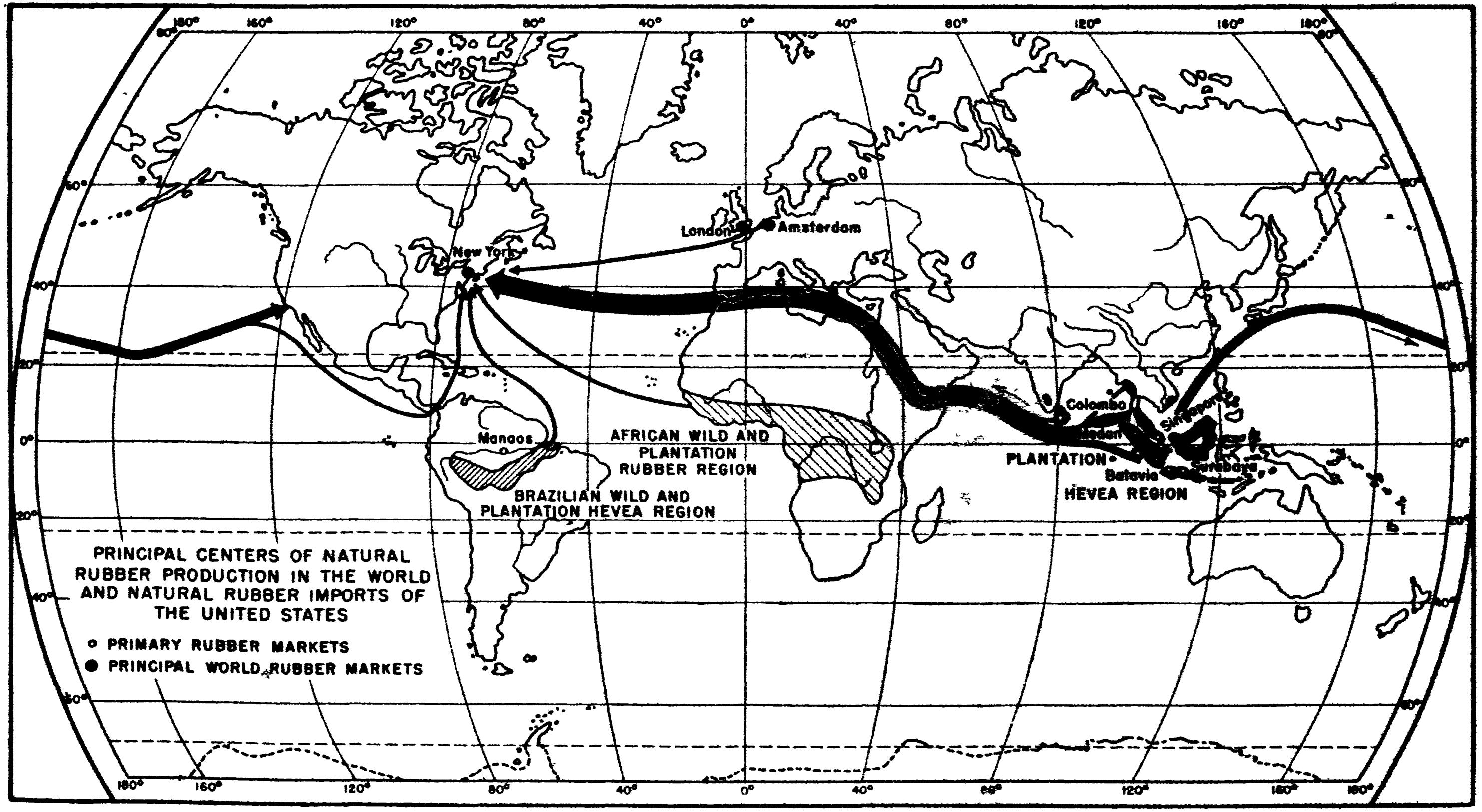
In recent years extensive plantations of oil palms have been established under western management in the Netherlands Indies (Sumatra) and British Malaya. This new plantation industry has proved to be a dangerous competitor of the African industry. The oil produced on the estates is more carefully prepared than native oil can ever be. It has a low content of free, fatty acids and is, therefore, in great demand.

The centers of consumption of palm oil are western Europe and the United States. The United States imports come principally from Sumatra, though Africa, especially the Belgian Congo, furnishes some. Most of the palm kernels are shipped to Europe, where the oil is extracted and used in the margarine industry.

Rubber

One of the most spectacular developments of the twentieth century is the growth of the rubber industry from a primitive gathering activity, carried on in the equatorial rain forests, into a major plantation industry of the tropics.

Rubberlike substances are known to exist in many plants of the intermediate as well as of the tropical regions. Thus far, however, the largest and most satisfactory rubber-producing plants have been found in warm regions where rainfall and humidity are high throughout the year. Among the numerous actual or potential producers, the Hevea tree (*Hevea brasiliensis*) has attained pre-eminence because of its high yields and the excellent quality of its rubber. The bark of this tree yields a ready flow of latex, a milky juice not unlike that of the American milkweed. It requires a


PRINCIPAL CENTERS OF NATURAL RUBBER PRODUCTION IN THE WORLD AND NATURAL RUBBER IMPORTS OF THE UNITED STATES
○ PRIMARY RUBBER MARKETS
● PRINCIPAL WORLD RUBBER MARKETS
New York
London
Amsterdam
Manaos
AFRICAN WILD AND PLANTATION RUBBER REGION
BRAZILIAN WILD AND PLANTATION HEVEA REGION
Colombo
Medan
Singapore
Batavia
Surabaya
PLANTATION HEVEA REGION
180°
160°
120°
80°
40°
0°
60°
20°

Projection after McKnight and McKnight.

Principal centers of rubber production in the world and rubber imports of the United States.

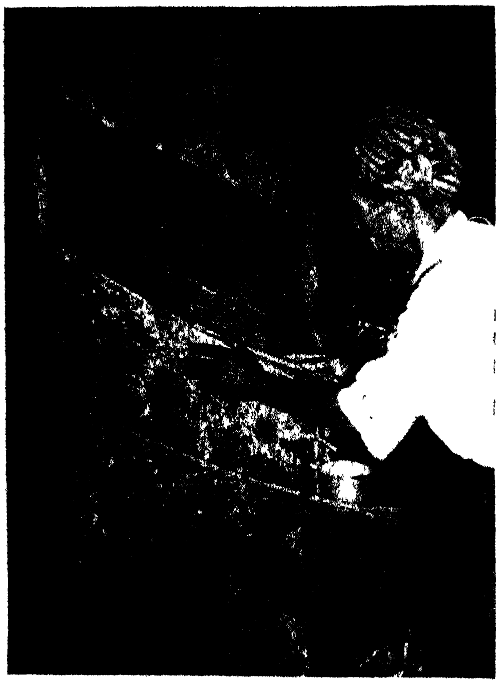
rainy tropical climate; a pronounced dry season is decidedly unfavorable, because it interrupts the flow of latex.

The Hevea grows wild in the extensive tropical forests of the upper and southern Amazon basin, where the latex was known to the Indians under the name of "Cahuchu" (wood tears) and was used by them to weatherproof their moccasins. Cahuchu, or caoutchouc, became known in Europe about the middle of the eighteenth century, and for more than a hundred years the commercial value of the product was based mostly upon its property of erasing pencil marks ("rubber"). Although the invention of the vulcanization process by Charles Goodyear in 1839 paved the way for large-scale use, rubber did not become of major industrial importance until the rapidly developing bicycle and automobile industries created an enormous demand for it. With a large part of the civilized world riding on pneumatic tires, rubber has become one of the raw materials indispensable to our present industrial age.

Change from wild rubber to plantations. The inhospitable tropical environment and the scattered distribution of the trees through the forest proved to be great handicaps in the exploitation of the wild rubber resources of the Amazon basin. It soon became evident that the supply of wild rubber was not sufficient to satisfy the ever-increasing demands. During the latter portion of the nineteenth century, efforts were made to introduce the Hevea in other parts of the world and to cultivate it in plantations. These attempts were highly successful, and at present more than 95 per cent of the world production of rubber is derived from these plantations. The wild rubber output of Brazil has fallen to a negligible percentage, though World War II stimulated some increase, at least temporarily.

Labor needs. Tapping the trees is laborious and requires considerable skill. (See Illus. above.) In order to have each tree tapped every other day, an abundant supply of low-priced labor is a necessity. Hence, plantations have been successful only in those sections of the Far East where an ample supply of cheap labor is available or can readily be imported. Thus, British Malaya and the Netherlands Indies have become the largest rubber producers in the world.

Methods of preparing rubber for shipment are relatively simple. In the Amazon region the latex was treated over fire and made into smoked balls. Coagulation of the rubber in the latex can be brought about also by the use of weak acids. Much rubber is made into thin, crêpy sheets, and some of it is even shipped as latex. The capital equipment necessary for the preparation of good sheet rubber is neither very complicated nor exceedingly expensive. An acceptable product can be made by relatively simple means. Thus, rubber



Courtesy Official Netherlands Information Bureau in U. S. A.

Tapping a rubber tree. Preparatory to tapping, an oblique incision is made in the bark. The rubber "milk" flows slowly into a cup fastened temporarily to the tree with a bamboo string.

can be produced successfully on plantations and by small native growers alike.

Rubber plantations in the Far East. In British Malaya the plantations are mostly on the low coastal plains; a few are in the hilly belt farther inland. Climatic conditions are ideal, but much of the labor is imported, mostly Tamils from India and Chinese from the southern part of China.

Courtesy Official Netherlands Information Bureau in U. S. A.

"Limburg," rubber estate in East Java, south of Malang. The plantation headquarters are surrounded by young and old rubber plantings.

In the Netherlands Indies rubber is produced in all the western islands. Modern rubber estates involving heavy investments of French, English, American, and Dutch capital exist in Java and Sumatra. (See Illus. above.) In some parts of the islands the natives have followed the example of western capital and have planted large areas to rubber trees. The product of these plantings, the so-called "native rubber," has become an important factor on the world market. The native producer has few overhead expenses. He need not worry about the labor problem, since usually the members of his own family and a few immediate friends do all the work; he does not have above him a board of directors and shareholders clamoring for dividends. Thus, he can tap his trees whenever prices are favorable, and when the market goes down he can discontinue tapping without incurring serious losses. True, the rubber he produces is of inferior quality, and its color is muddy and unattractive in comparison with the beautiful creamy white sheets produced by the European plantations. Nevertheless, it brings only slightly lower prices.

This native competition raises a serious question for the plantation rubber industry. After all, rubber is only a raw material of industry, and it does not need the extreme care given to it on the estates. The Hevea is a hardy tree and lends itself well to the rather shiftless methods of native cultivation. On the other hand, the plantations can carefully select high-yielding trees and graft parts of these on low yielders. It is possible, however, that in the rubber, as in the coconut industry, the largest share of the world production may eventually be contributed by native growers, provided synthetic rubber does not become so cheap and good as to make natural rubber production economically impossible.

Considerable quantities of rubber are produced also in Ceylon, British Borneo, southwestern Siam, French Indochina, and India. Indochina and India are handicapped by the existence of a pronounced dry season. A little Hevea rubber, somewhat less than 1 per cent of normal world production, is now produced on plantations in Liberia on the west coast of Africa; and there are smaller plantations at Belterra in the lower Amazon Valley. In all these areas the labor supply seems to be the problem most difficult to solve.

Some wild Hevea rubber from the Amazon basin still reaches world markets. This is the so-called Para rubber, a highly esteemed smoked rubber prepared according to the old laborious processes of Brazilian native tappers.

Photo by A Fagle

Harvesting sugar cane with machetes in Cuba

Guayule (*Parthenium argentatum*), a bush of the dry regions of Mexico, has been exploited commercially for some time in Mexico, contributing a fraction of 1 per cent to world production. Expansion of this industry, however, seems to be possible.

Most synthetic rubbers are derived basically through polymerization processes from a small group of hydrocarbons of which butadiene is perhaps the best known. These "dienes," since they are hydrocarbons, can be derived from coals, crude petroleum, and even from alcohols, which thus constitute the major basic raw materials of this industry. Qualities of some of these rubbers are good, some of them being more resistant to oils and to abrasion than natural rubber. However, natural rubber can still be produced the more cheaply, and has certain valuable qualities which the synthetic product does not possess.

In all modern countries rubber is used in large quantities and for many purposes. The United States, with its vast numbers of automobiles, is by far the most important consumer of rubber, chiefly for the manufacture of tires. The city of Akron, Ohio, is the principal center of the rubber-manufacturing industry.

Sugar Cane

The sugar cane (*Saccharum officinarum*) is a native of southern Asia, probably of India, where it was known in earliest times. During the later Middle Ages, it was grown in the countries around the Mediterranean, but climatic conditions were not favorable enough to induce any large-scale development of the sugar industry there. From the Mediterranean, however, the crop spread rapidly westward, first to the islands off the African coast, thence to the newly discovered American continents, where a flourishing sugar industry, based primarily upon imported black slave labor, became established in the Antilles and Brazil. As a result of this development, cane sugar ceased to be a luxury and became an article of common consumption.

Climate conditions. Although some varieties of sugar cane ripen within a period of about eight months, most of them require a long growing season, from 12 to 24 months. As frost is detrimental to cane, the cultivation of this crop is generally limited to the frost-free areas of the world. Furthermore, the continuous high temperatures which the plant requires, above 70°F. and preferably around 80° to 85°F., restrict successful cultivation to the warmer parts of the earth.

During the growth of the cane an abundant supply of moisture is essential, either as rain or, better still, by irrigation. A combination of much sunshine and a damp tropical atmosphere is most favorable for the development of thick, tall cane, rich in sugar. (See Illus. p. 126.) During the period of ripening, dry weather is essential —heavy rains during this critical period lead to an appreciable dilution of the juice, and hence to a lower percentage of sugar. Sugar cane, therefore, cannot be cultivated to economic advantage in the very humid tropics, as for example in the Amazon or the Congo basins. The world's commercial sugar plantations are therefore confined principally to tropical lands where there is a short dry season.

In both hemispheres, but especially in the northern, sugar cane reaches well into the subtropics, as in northern India, southern China, and southern United States. There the shorter growing season results in cane of smaller size and lower sugar yield per acre than in the tropics.

Production and distribution. In the commercial production of cane sugar, one of the principal problems arises from the fact that cane is a raw material of great bulk, and during a brief harvesting season huge quantities must be transported quickly to a central crushing plant, where the raw sugar is extracted. Commercial production of sugar cane therefore tends to be confined to lowland areas where transportation is easy. Most plantations are large, so that efficient transportation systems can be established. Such systems usually consist of a network of narrow gauge tracks over which small engines can draw long trains of heavily loaded cars. In many regions, additional cane is grown by natives and sold to neighboring "centrals." (See Illus. A, p. 128.)

The modern processes of sugar refining are rather complicated and require costly machinery as well as a high degree of technical skill. The commercial manufacture of sugar is therefore largely in the hands of large corporations with ample capital at

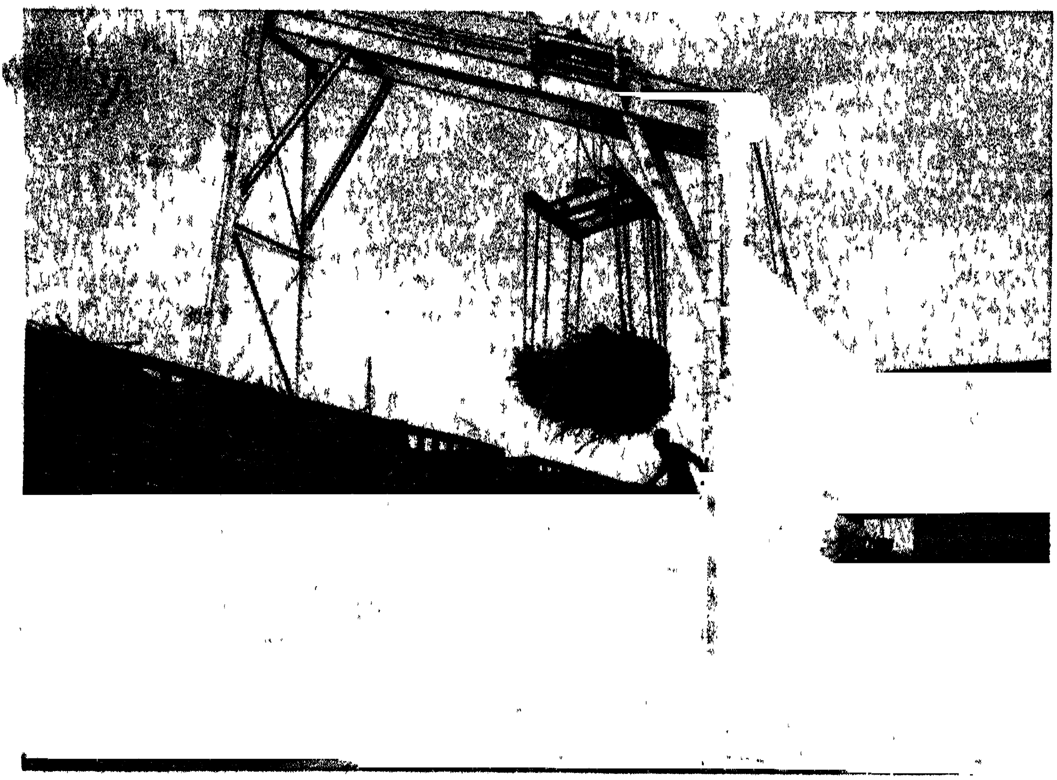


Photo by A. Lagle

(A) Loading cane from modern field cart to special railroad cars for shipment to the mill

Photo by A. Lagle

(B) A typical large Cuban sugar mill. Note loaded cane cars in the foreground.

their disposal. In contrast to the rubber and copra industries, the sugar industry thus far has had little to fear from native competition. (See Illus. B, p. 128.)

The two outstanding surplus producers of cane sugar are Cuba and Java. The conditions under which cane is grown in these two islands are vastly different. (See Illus. p. 130.)

Except for the occasional occurrence of severe droughts, Cuba enjoys a climate that is ideal for sugar cane. Only 12 to 15 months are required to mature the crop, and once the cane is in the ground the rootstocks continue to send out new shoots for a number of years, thus eliminating the cost of replanting the fields after the harvest. Fertile land is abundant and cheap. On the other hand, the population is rather sparse and labor is high priced. The cane farmers or "Colonos," who sell their cane to the numerous large mills, give only indifferent care to their crops. As a result, the yields of sugar per unit of area are low.

TABLE I

PRODUCTION OF CANE SUGAR IN PRINCIPAL PRODUCING COUNTRIES

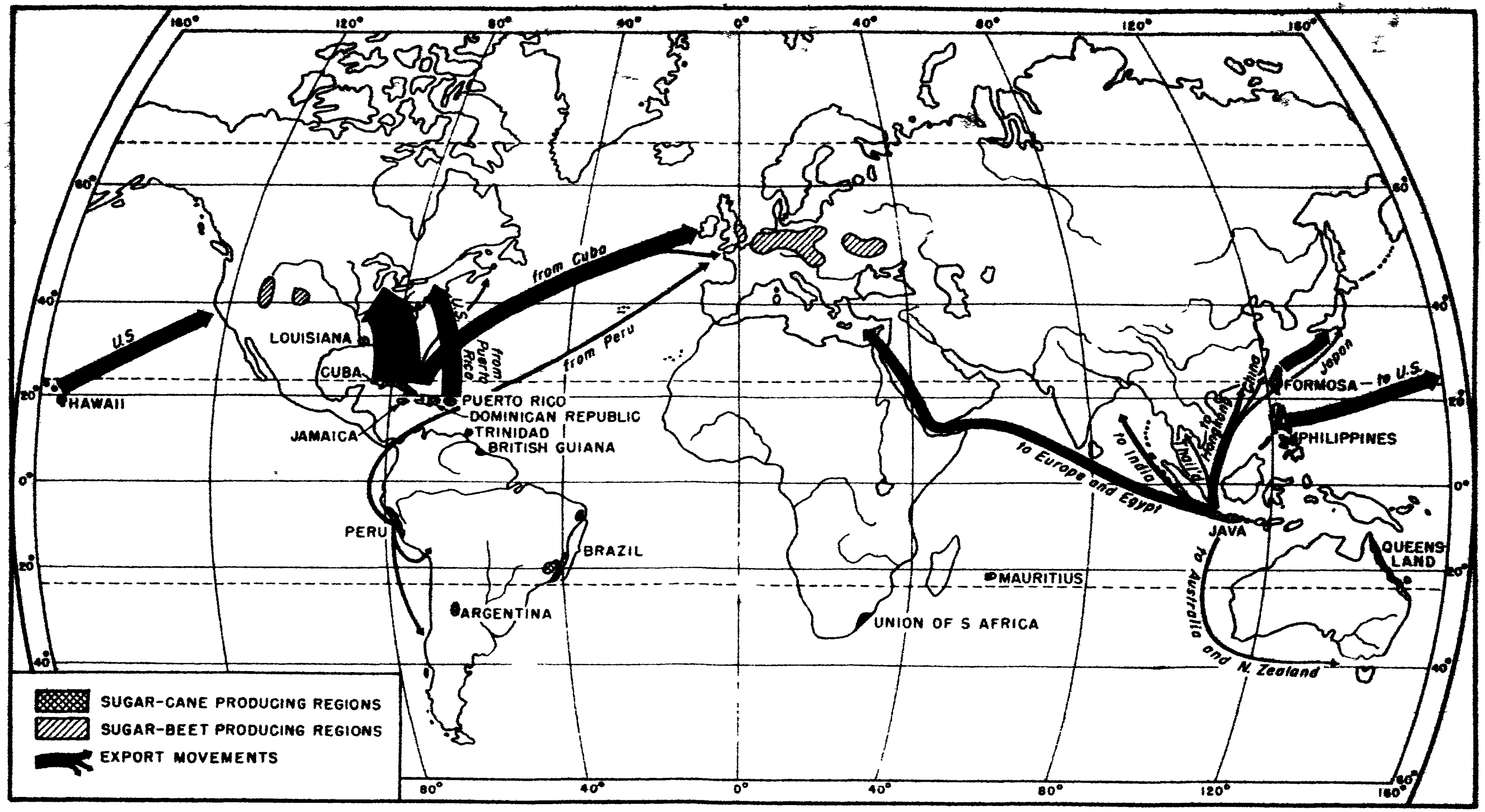
Countries	*In 1,000 Quintals* Av. '34-'35 to '38-'39	1943-1944	1944-1945	1945-1946
Cuba . .	26,729	40,514	33,535	37,279
United States	3,615	4,222	3,705	4,087
Mexico .	2,978	3,902	3,729	4,236
Puerto Rico. .	7,940	6,200	8,270	7,570
Dominican Republic. . .	4,112	4,525	4,376	4,240
Argentina. . . .	3,993	4,098	4,590	4,470
Brazil.	10,395	12,546	12,500*	No data
Peru.	3,958	4,183	4.231	No data
Formosa.	10,786	8,900*	5,000*	1,600*
India.	32,112	35,651	33,414	32,841
Java	10,805	4,968	842	250*
Philippines. . .	8,570	19	6	111
Mauritius. . .	2,790	3,107	1,996	1,390
Union of South Africa . .	4,087	5,311	5,572	5,017
Australia . . .	7,068	5,003	6,113	5,456
Hawaii .	8,324	7,418	6,962	5,936

* Estimates.

Source: *International Yearbook of Agricultural Statistics*, 1941-42 to 1945-46, Bureau of the F.A.O. in Rome, Vol I, Rome, 1947.

Since Cuba gained independence, the sugar industry has expanded rapidly because of the influx of American capital and the preferential tariff accorded by the United States to raw sugar imported from the island. In recent years the industry has spread from the central provinces to the level lands of the east, but large areas are still available for future expansion. The United States is the principal market. The sugar is imported raw to be refined in or near the North Atlantic ports, especially Philadelphia, New York, and Baltimore, or the Gulf port of New Orleans.

In Java, sugar cane can be grown successfully in the low coastal and interior plains of the central and eastern portions of the island, where a brief dry season, the so-called "East Monsoon," insures the necessary concentration of the juice. As Java is densely populated, only limited areas are available for the cultivation of sugar cane by plantation methods. The sugar companies have to rent land from the natives and can do so only for periods of time just long enough to produce one crop. Thereafter the land is returned to the owners and other areas are rented. The entire system is under strict control of the government of the Netherlands Indies, which is interested in reserving an adequate amount of land for the production of foodstuffs. Although the volcanic soils are fertile and labor is cheap, the high price of land and the necessity of planting each crop are distinct handicaps to the Java sugar industry. These handicaps have been met by a highly intensive system of agriculture and close cooperation between planters and scientists. The annual yield of sugar per acre is much higher in Java than anywhere else in the world. Most of the crop is refined on the island and subsequently exported to India, parts of the Far East, and Egypt. The establishment of a high protective tariff on sugar in India was a sudden and severe blow to the Java sugar industry, resulting in a great decrease in production and causing large capital losses. In recent years,



Projection after McKnight and McKnight

Principal centers of commercial production of sugar cane and international trade in cane sugar increasing quantities of sugar from Java have gone to the European markets owing to decrease in Japanese demands and the Indian tariff.

Among the other producers of cane sugar in the Western Hemisphere should be mentioned Hawaii, Puerto Rico, the Dominican Republic, Peru, Brazil, and Argentina.

The Hawaiian Islands have an oceanic climate with rather moderate temperatures, so that the cane requires a growing season of 20 to 24 months. On the northeast or windward side of the islands precipitation is abundant, while on the dry leeward side the scanty rainfall must be supplemented by irrigation. The rugged topography has necessitated expensive engineering works for irrigation and transportation, while much of the labor has to be imported from various parts of the Orient. Practically the entire Hawaiian export is sent to the United States, to the refineries on the Pacific and Atlantic coasts.

In Puerto Rico the sugar is produced in the low coastal plains, especially those of the north coast, and the surplus is exported principally to the United States. The Dominican sugar industry is concentrated in the low southern coastal plain. In South America, Peru is an important sugar producer and exporter. There the cane is grown under irrigation in the valleys of numerous rivers which cross the coastal desert. In view of the limited quantity of available irrigation water and the competition of other crops, such as cotton, little further expansion of the sugar industry can be expected. Brazil, though it has important production, exports but little sugar, while Argentinian production is entirely for the domestic market.

In continental United States, southern Louisiana has the major sugar cane district. Florida's production is much less but is increasing. Though important from a national point of view, United States production is of little consequence from the standpoint of world supply.

The Philippines, Formosa, Queensland, Natal, Mauritius, and Réunion are commercial producers in the Eastern Hemisphere. In the Philippines, sugar became an important crop because of tariff preference on the American market; more than 95 per cent of the exports were sent to this country. The largest sugar estates are on Negros, Cebu, Luzon, and Leyte. It remains to be seen how promptly and to what extent there will be recovery from the damages resulting from World War II, and for what length of time the United States will continue to give high customs preference to Philippine sugar.

Mauritius and Formosa produce sugar chiefly for export, the latter exclusively for the Japanese market, at least before the war. The sugar industry of Australia is concentrated in the narrow eastern coastal plain of Queensland and is unique because white labor is used exclusively.

Important contributors to world production are India and southern China. As far as the quantity of sugar produced is concerned, India ranks in importance above Java and Cuba. A considerable portion of the crop is not refined but is consumed in the form of brown sugar, the so-called "gur." In recent years, however, the production of modern refined sugar has increased greatly, and with this has come a significant increase in commercial acreage of cane.

The sugar industry furnishes some excellent examples of how man's interference through tariffs and import quotas can greatly diminish or even completely neutralize the physical and other advantages of certain regions, or how it can keep in production other areas which, under a system of really free enterprise, would not be able to grow sugar on a competitive basis.

Coffee

Of the numerous nonalcoholic beverages, coffee ranks first in commercial importance, followed by tea and cacao. Well over three billion pounds of coffee beans are exported annually from the major producing countries, a convincing measure of the magnitude of this trade. Tropical America is the principal source of the world's coffee supply.

Natural conditions favorable for coffee culture. Coffee is a typical highland crop of the tropics. It does best at altitudes of 1,000 to 6,000 feet, where the days may be quite warm, 90°F. or more, but where the temperatures at night may occasionally drop as low as 40°F. Coffee requires much moisture—an annual rainfall of 50 to 90 inches—but a relatively dry period during the picking season is desirable. In general, hillsides rather than valleys are preferred as sites for plantations, because coffee grows best where air and water drainage are adequate.

Courtesy Official Netherlands Information Bureau in U. S. A.

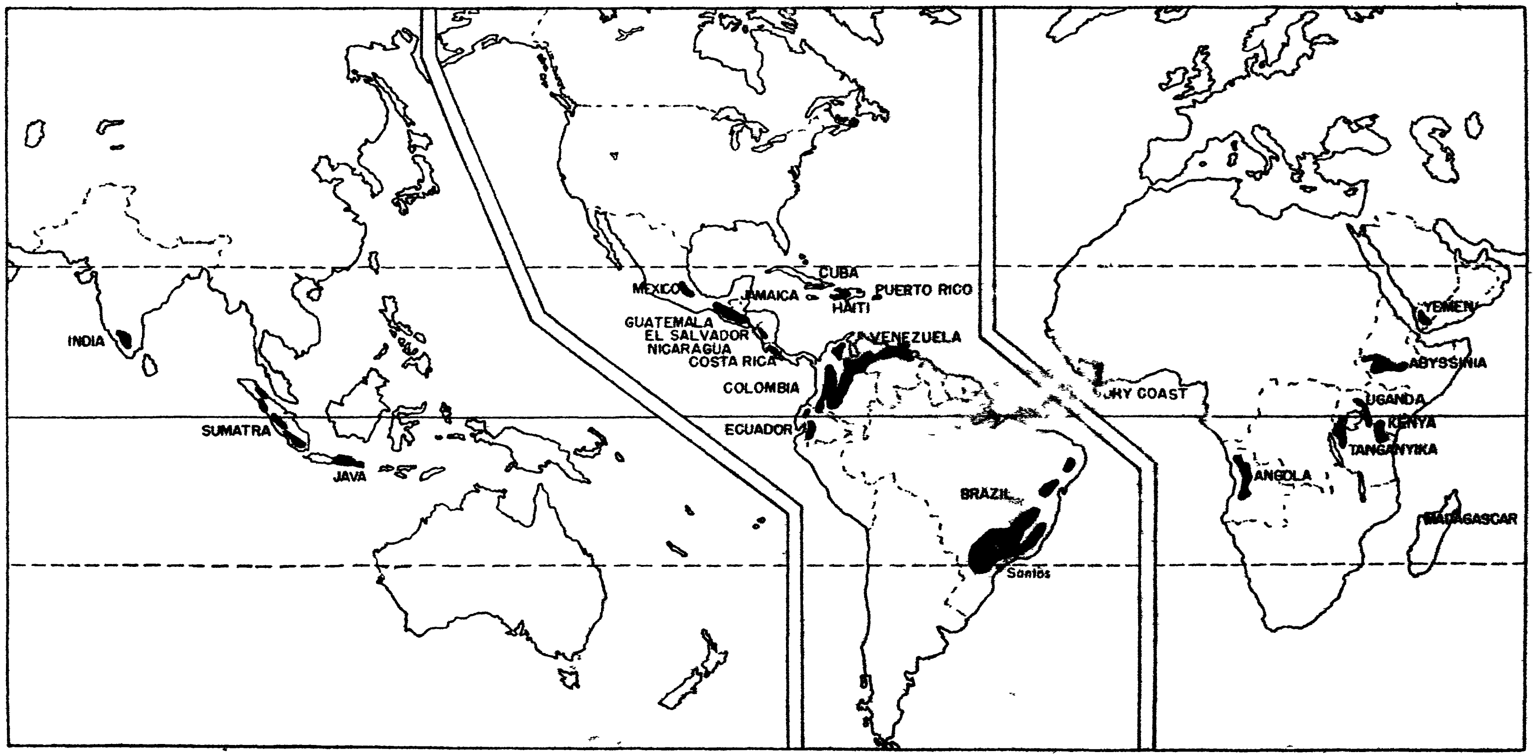
Coffea robusta. Plant with berries and flowers.

Rich soils are needed for coffee production. Inasmuch as heavy rainfall, which causes loss of soil fertility by leaching, is nevertheless a plant requirement, it is apparent that not all the areas with a tropical highland climate are good coffee lands. The soils most favored for plantations are those of volcanic origin, where weathering is actively breaking down lavas and liberating the essential plant foods. The finest coffee lands of Java, Sumatra, Brazil, Colombia, Central America, and Mexico all have rich and deep, loamy soils derived from young volcanics. On the best coffee lands in Central America and Brazil, the loose mantle rock is said to reach depths of over a hundred feet.

Although many species of trees and shrubs belong to the genus *Coffea*, only a few have been found suitable for coffee production. These are *Coffea arabica* and *Coffea robusta*, both tall shrubs, and *Coffea liberica*, a small tree. The first named is probably a native of Abyssinia and grows best in tropical highland areas, whereas the latter two are natives of the Congo basin and of Liberia and do well at somewhat lower altitudes. Most of the commercial coffee crop of the world is a product of different varieties of *Coffea arabica*, prized because of the superior flavor of the beverage made from the beans of this species. *Coffea robusta*, because of its resistance to fungus diseases, is grown extensively in the East Indies, while some *liberica* is still grown in Africa. (See Illus. left.)

Present distribution of the coffee industry. From its original indigenous home in the highlands of Ethiopia, coffee culture gradually spread to Arabia, India, the East Indies, and the Western Hemisphere. The early Red Sea port of Mocha, from which coffee first was introduced to Europe, and the later center of production in Java, have left their names in coffee terminology. After about 1880, however, fungus diseases destroyed most of the Javanese and Ceylon plantations, and the cultivation of *Coffea arabica* became unprofitable in the East. The chief centers of production shifted to their present location, in South and Central America and the West Indies.

At present, the commercial crop of the New World comes largely from the well-watered highlands of southeastern Brazil, Colombia, Venezuela, Central America, southern Mexico, and the higher slope lands of Haiti, Puerto Rico, and Jamaica. In the



Principal coffee producing regions of the world and principal ports of export.

Old World the principal regions of production are the Netherlands Indies, the Ivory Coast, Angola, Madagascar, Belgian Congo, Kenya, Uganda, and Tanganyika. Small quantities are produced in Yemen (Arabia), India, and Abyssinia. (See Illus. p. 133.)

South America contributes from 70 to 73 per cent of the coffee exports of the world. Among the exporting countries, Brazil easily ranks first, although its fraction of the total world exports declined from about 75 per cent in 1906 to 52 per cent in 1945. Colombia in recent years has furnished about 20 per cent of the total coffee exports, while El Salvador held third place with about 4 per cent. Coffee production in the Netherlands Indies, which formerly held third place, has been low in recent years, owing to postwar political disturbances. The share of Africa in the world's coffee exports has increased steadily from about 5 per cent in the early nineteen thirties to over 10 per cent in recent years.

Courtesy Merrill Lynch, Pierce, Fenner, and Beane.

General view of a large coffee plantation in Brazil

Brazilian production is still the dominating factor in the world's coffee markets. In the state of Sao Paulo the light green of the plantations is the most conspicuous feature of the cultural landscape. The principal producing region is the southeastern plateau, a highland area which slopes westward from the Coast Ranges toward the Paraná River in the interior, particularly in São Paulo and adjacent sections of Minas Geraes. On this plateau, at altitudes of 1,000 to 2,500 feet, are thousands of square miles of rich, red soil capable of producing several times as much coffee as the world needs. The rainfall, about 60 to 75 inches per year, is mostly favorably distributed, the major part occurring during the growing season of the coffee berry, while the cool period of the year, May to September, is relatively dry. This is the ripening and picking season. The coffee crop reaches maturity and is ready to pick early in May, and picking lasts until September. Inasmuch as coffee picking can be done only by hand, this one-period harvest involves a larger labor need than where the ripening period is more prolonged, as is the case in some of the regions of northern South America. (See Illus. p. 134.)

Since coffee is the principal support of a large part of the population in Brazil, it is obvious that failure of the crop or a prolonged period of overproduction will result in economic distress.

Because of the large profits which were formerly realized by the Brazilian growers, the acreage in coffee plantations was enormously increased. Lack of careful study of potential market demands, and lack of planning in accordance with demands, led to overexpansion, overproduction, and disastrously low prices. The Brazilian government therefore resorted to a system of price control, buying up large stocks of coffee with the idea of holding them until prices improved and then releasing them gradually. In its earlier stages, this so-called "valorization" scheme met with considerable success. Soon, however, the artificially sustained Brazilian prices made it profitable for other countries to increase coffee production. The accumulated Brazilian surpluses could not be absorbed by the existing markets, little was done to develop new markets, and for years it was considered necessary to destroy large stores of coffee without any return. The attempts of any single nation to increase prosperity through a permanent policy of destruction seems doomed to failure in the majority of cases and in addition hurts the world standard of living. Planning through international co-operation on a sound economic basis is necessary even where one country holds such undisputed leadership in production as Brazil holds in coffee.

Every country of the Western Hemisphere from Paraguay to southern Mexico produces some coffee. Production has been increasing on the highlands which extend from Venezuela and Colombia through Central America into southern Mexico, because of the favorable soil and climatic conditions and the fine-flavored coffee grown there. Increased plantings have been fostered by the high price of coffee, the low prices of suitable land, and the accessibility of the American markets. It seems probable that further expansion will occur in these regions.

Commercial production is also important in the Greater Antilles: Cuba, Haiti, the Dominican Republic, Puerto Rico, and Jamaica. Haiti has a well-developed market in France because of former colonial ties. Cuba can expand her production, although sugar has been in a better competitive position and hence has received principal attention. Puerto Rico is favored by an abundant labor supply and close trade connections with the United States. The Blue Mountain coffee of Jamaica has the reputation of being equal to the world's best and commands a premium in European markets.

In the Eastern Hemisphere, the Netherlands East Indies led in export trade before

TABLE II

EXPORTS OF PRINCIPAL COFFEE-PRODUCING COUNTRIES

Countries	*In 1,000 Quintals*			
	1931-1938 Av.	1943	1944	1945
Costa Rica	232	242	188	218
Guatemala	473	498	513	513
Haiti	278	258	231	300
Mexico	365	343	357	· 357
Nicaragua	153	120	131	122
Dominican Republic	103	106	82	177
Salvador	541	561	631	577
Brazil	8,748	6,067	8,133	8,503
Colombia	2,298	3,150	2,954	3,090
Ecuador	137	123	145	100
Venezuela	477	290	200	No data
Netherlands Indies	815	No data	No data	No data
Angola . .	164	293	238	309
Belgian Congo	155	221	149	No data
Kenya and Uganda	262	273	224	224
Madagascar .	240	124	453	269
Tanganyika .	148	110	158	146

Source: *International Yearbook of Agricultural Statistics*, 1941-42 to 1915-46, Bureau of the F.A.O. in Rome, Vol. II, Rome, 1947.

World War II. The coffee is grown mostly in the mountains of eastern Java and western Sumatra, chiefly between altitudes of 1,000 to 3,000 feet. The principal species planted is *Coffea robusta,* because of its resistance to fungus diseases, although in some districts *Coffea arabica* is still grown. In Arabia coffee is produced under irrigation in the coastal kingdom of Yemen, where the processes of cultivation, picking, and curing are under the supervision of British experts. Arabian coffee is considered to be of superior quality and generally commands high prices in European markets. Thus, the British, though more widely known for their tea, produce fine coffee in both Arabia and Jamaica.

International trade in coffee. For a long time the world trade in coffee flowed principally from the West Indies and Netherlands East Indies to Europe. Now the world's chief coffee stream is from Santos and Rio de Janeiro to New York, with lesser streams from Cartagena and Puerto Colombia (Colombia) to New York, from Brazil and the East Indies to western Europe.

Nearly half of the coffee exports of the world go to the United States. Our consumption has risen from three pounds per capita in 1830 to an average of over 15 pounds for the period 1940-1947. Since more than half of the United States imports come from Brazil, the commercial and economic ties between the two countries are close. The increase in imports from more northern tropical countries has slightly reduced the percentage received from Brazil, owing to the preference in the United States for a larger admixture of mild coffees in the blends.

Coffee, an inexpensive luxury, has achieved mass appeal as a beverage. It cheers alike the laborer, the student, and the society matron. Its introduction had to overcome religious, political, and physiological prejudices, and in many countries even now its use is hampered by economic barriers in the form of taxes and duties. It has, however, won such universal favor that its position as one of the great commercial products of the world seems permanently assured.

Spices

In the minds of many inhabitants of middle and high latitudes, spices are more intimately associated with the tropics than is any other product. This association of ideas is, however, chiefly a survival of times past. The spices now are only a minor portion of tropical products entering world trade.

In many tropical countries the food of the natives is highly seasoned. Spices have been known and used for untold centuries in the warmer regions of the earth. Whether this is a physiological response to climatic conditions or whether it is the result of the tastelessness of the native diet, particularly of rice, remains an open question.

Even in pre-Roman times small quantities of spices reached the West, and, according to some, became immensely popular among the rich because of the often doubtful quality of the meat in a region with hot Mediterranean summers and without means of refrigeration. The later famous spice trade was partly responsible for the wealth of Venice and Genoa, for the discovery voyages of Portuguese and Spanish, and for the foundation of Colonial empires, such as those of Great Britain and of the Netherlands. Spices were compact and very valuable, and they kept well. They were therefore eminently suitable for an early trade which could deal only in luxuries because of slow, hazardous transportation and the small size of a camel's load or even of a ship's cargo.

Most of the spices which once brought their weight in gold are now common kitchen ingredients; and although they have lost their dominant place in trade with the tropics, the volume of shipments of many spices is vastly greater than it was in the sixteenth and seventeenth centuries.

Distribution. Among the spices, *pepper* (*Piper nigrum*) stands first. It is a vine which, like ivy, fastens itself to a support—a pole or a living tree with not too dense a crown. The pepper plant can be grown only where temperature and humidity are constantly high. The fruit is a red berry which grows in bunches of 20 to 50; each berry contains one seed, the real peppercorn. If picked green and dried, the berries become dark and wrinkly, the pericarp adhering to the seed. This is the so-called *black pepper*. In *white pepper*, the pulp has been removed from the seeds. (See Illus. above.)

Courtesy Official Netherlands Information Bureau in the U S A

Picking pepper. The pepper is in the form of berries which are first green, then red, and then yellow, when they are ripe. After being picked, they are dried on mats in the open air and finally turn black.

The Netherlands Indies is the principal producer of pepper, accounting for more than 70 per cent of the world production. The pepper gardens are mostly in the hands of the natives, but the trade in pepper, which centers in Batavia, is dominated by Chinese.

India produces small amounts of pepper on the warm and humid Malabar Coast, the "Pepper Coast," which was one of the principal goals that led Vasco da Gama to make the first direct sea voyage from Europe to the Orient. Minor centers of production are found on the southwest coast of French Indo-China, Sarawak, Ceylon, and British Malaya. Malaya shows unexpectedly high exports. A large percentage of these exports, however, originate in the near-by Netherlands East Indies and are sold through the important Malayan trade centers of Singapore and Penang.

Cloves are the dried flower buds of a tropical tree (*Eugenia caryophyllata*), found originally in wild state in the Molucca or Spice Islands. During the seventeenth and eighteenth centuries the Dutch had a virtual monopoly on the trade in cloves. This monopoly was broken by the French, who succeeded in transplanting some clove trees to their island possessions in the Indian Ocean (Réunion). At present, most of the cloves entering world trade are produced on the little islands of Zanzibar and Pemba, on the east coast of Africa, which enjoy a warm and very humid climate.

Cinnamon is the inner bark of a small tree (*Cinnamonum zeylanicum*), cultivated principally in the damp lower hills and coastal plains of southwestern Ceylon, while Java is a minor center of production. Since the aim of the cinnamon industry is to obtain as much bark as possible, the plant is pruned to bush form. During the rainy season branches of a certain length are cut, and the bark is carefully peeled off and dried. Closely related to the Ceylon cinnamon is *cassia*, a product of wild or cultivated varieties of cinnamon trees which grow in India, the Netherlands Indies, French Indo-China, and southern China. This is inferior to the Ceylon product, but it is often used as a substitute for it.

The *nutmeg* tree (*Myristica fragrans*) also requires a truly tropical climate and is grown mainly in the Netherlands Indies. Once one of the highly valued spices, the nutmeg has lost much of its former popularity.

The *vanilla* plant is an orchid which entwines itself around trees. Because it needs dry weather during the flowering period, it is best adapted to the marginal areas of the tropics, where pronounced dry seasons prevail. The principal producers of vanilla are southern Mexico, Réunion, the humid north and east coasts of Madagascar, and neighboring islands. In recent years the industry has suffered greatly from the competition of synthetic vanilla, which has a much stronger flavoring power than has natural vanilla.

Among other essentially tropical spices should be mentioned *ginger* (*Zingiber officinale*)—the rhizome of a plant which is cultivated in the marginal districts of the tropics, and even in the subtropics (southern China, India, Jamaica)—and the *Cayenne pepper* or *chili* of Central America, the West Indies, and Mexico.

Medicinal Products

The tropical regions are important sources of a number of medicinal products, among which *quinine* is undoubtedly the most valuable. Quinine and mosquito netting are in many parts of the world practically the only means to combat that great scourge of humanity, malarial fever. Quinine is extracted from the bark of the cinchona tree, which grows wild in the forests of the eastern slope of the Andes Mountains. It is a tree of the tropical highlands occurring mostly at altitudes between 3,000 and 8,000 feet. As a result of the inaccessibility of the Andean forests and the destructive methods formerly practiced by the native searchers for bark, there has developed a plantation industry whose output has superseded almost entirely that of the wild tree. This industry centers in the East Indies, especially on some of the mountain slopes of western Java, and now supplies more than nine-tenths of the world's quinine.

Outside of the Netherlands East Indies, cinchona plantations are found in India on the slopes of the Himalayas and at Madras, while small quantities of South American cinchona still reach the principal markets.

The leaves of the *coca bush* (*Erythroxylon coca*), which is grown on the eastern slopes of the Andes between elevations of 2,000 to 5,000 feet, are chewed by the Indians during work and on the march. The stimulating effect of the leaves is due to their content of cocaine, an indispensable drug to the medical profession, though dangerous and habit forming when wrongly used.

Similar but much less dangerous stimulating alkaloids are contained in the *kola nut*. This is the seed of the kola tree (*Sterculia acuminata*), which is grown extensively by the natives of western Africa at the edge of the tropical forest. The kola nut is the chewing gum of Africa, and in polite African society it plays the same role that a cigar or a box of candy plays in our Western culture sphere.

Tropical Woods

Perhaps the greatest resources of the areas of rainy tropical climate are the immense tropical rain forests which cover with a heavy mantle of everlasting green so much of northern South America, Central Africa, and the Australasian islands. These forests, in contrast to most of those in higher latitudes, consist almost entirely of hardwoods. Softwoods—that is, coniferous trees—grow in some places, particularly on plateaus and higher mountain slopes, but their total acreage is small in comparison with that of the hardwoods. (See Map of World Vegetation p. 88.)

The tropical rain forests have no prolonged annual period of rest. Conditions throughout the year are so favorable for assimilative processes that many species do not show the pronounced growth rings which are so typical of the trees of the middle latitudes. Many tropical woods have a fine, even texture, and some are remarkably hard and heavy. Various types of so-called "iron woods," with a specific gravity greater than that of water, are common throughout the rainy tropics.

Commercial production. Notwithstanding the excellent quality of some of the wood, only a very small percentage of the tropical timber resources is commercially exploited at the present time. In a few regions agriculture, in its search for new virgin crop lands, is making extensive inroads into the rain forest. Such is true, for example, in the cacao districts of the Gold Coast, where the British colonial government has considered it necessary to declare parts of the tropical forest permanent reserves. Similar reserves have been set aside in the Netherlands Indies and are being gradually expanded for the protection of the watersheds. Nevertheless, the tropical rain forest is as yet a reserve of timber which is relatively untouched.

For several reasons the tropical hardwood forests have not gone the way of most of the hardwood and a considerable part of the softwood forests in Europe and North America. In the rain forest, although they are not completely absent, pure stands of trees rarely occur. In an acre of tropical forest one will find, as a rule, dozens of different species of trees. Such greatly mixed stands seriously handicap commercial exploitation. Furthermore, a certain percentage of the timber, because of too fast growth, may be of rather poor quality, with coarse or uneven texture. To this must be added numerous difficulties of a physical nature: unhealthful climate, undergrowth, and soft, swampy ground. Transportation is laborious and expensive, and shipping points are usually far from the centers of consumption.

Under such conditions, and as long as great quantities of timber for ordinary purposes can be cut at relatively low cost in the middle latitudes, the "utility" hardwoods of the rain forest cannot compete in world markets. Only those woods which excel because of grain, color, hardness, or fragrance, the so-called precious or cabinet woods, can stand the high cost of production and marketing. Of these, a considerable number, under greatly varying names, reach the western markets. One of the principal handicaps of the trade in tropical woods is that, from a botanical point of view, the forests are still imperfectly known; wood of widely different species of trees may have similar popular or trade names and similar appearance, yet have greatly different properties.

Some of the precious and semiprecious woods have been made the objects of wide search, and their names have become familiar in most of the Western World. Mahogany, cedar, and teakwood rank foremost in this respect.

Distribution. True *mahogany* (*Swietenia*) is much sought after for fine cabinet work. It is moderately hard, has a beautiful grain and a rich color which improves with time, and can be applied as a veneer. It occurs only in southern Mexico, Central America, the West Indies, and northwestern South America. At present, Mexico is the largest shipper of mahogany, whereas Honduras and British Honduras have always been noted as producers of exceptionally fine types of this wood.

Several species are closely related to *Swietenia*, of which the wood is similar and to which the name mahogany is often applied. Among the most important of these is the African mahogany (*Khaya ivorensis*) of the Guinea Coast forests. The Ivory Coast is the principal exporter of this type of wood. Southeastern Asia also produces some woods that resemble true mahogany.

A type of wood that always conjures up pictures of tropical lands is *ebony* (*Diospyros ebenum*). Ebony, slaves, and ivory once were the principal products of trade in tropical Africa, and ebony was sought after as early as the days of King Solomon. The wood is very hard, usually coal black, and exceedingly fine grained. The trees that produce it are found in the forests of southeastern Asia, Africa, and Madagascar. Several other woods closely resemble ebony and often are sold under that name.

Where accessible, the tropical *cedars* (*Cedrela*) have been exploited to the verge of extinction. Cedar wood is reddish, soft, and fragrant. Especially because of the fragrance it is in great demand for the manufacture of cigar boxes. Cedar trees have a wide range, from southern Mexico to southern South America. The cedar trees of the Far East (*Toona*) are closely related to the true cedar, and their woods are practically identical. Central America, Brazil, and Mexico furnish most of the tropical cedar now used.

Teakwood (*Tectona grandis*) is in great demand for its strength and durability. The teak tree does best where there is a dry season of several months' duration. It is found, therefore, most abundantly in the deciduous monsoon forests of southeastern Asia, especially in Burma, Siam, eastern Java, and the Philippines. Since teak occurs in pure stands, it can easily be exploited. At present some of the principal stands of teak trees are under scientific silvicultural management, such as the "djati" forests of Java.

Among the large number of other tropical woods may be mentioned *sandalwood*, *satinwood*, and *rosewood*.

Other important economic products of the tropical forests are the resins and nuts, the harvest of which in many of the more sparsely settled districts constitutes the principal source of cash income for the native population. Among the various kinds of resins, the best known are the *hard copals* and the *soft copals* or *damars*, furnished by a number of different species throughout the tropics. The hard copals are used extensively in the manufacture of varnishes and are exported mainly from East Africa, Madagascar, the Guinea Coast, the Congo region, and southeastern Asia.

Southeastern Asia is the principal source of *rattan*, the stem of a liana, used in the manufacture of chairs and cane seats for chairs. Among the nuts of the warm rainy forests the best known are *tagua nuts*, *corozo nuts*, and *Brazil nuts*. The first two furnish the so-called vegetable ivory used in the manufacture of buttons, while the latter is an edible nut in high favor in American and European markets.

The Cattle Industries

In the warm lands cattle are raised chiefly for noncommercial purposes, for power, meat, and milk. India outranks all other countries of the world in total cattle population, having about 200,000,000 cattle and water buffaloes, compared with about 68,000,000 in the United States. The great majority belong to the humpbacked or zebu species. The bullocks are used as draft animals, the cows furnish a little milk. The Hindus are forbidden by their religious beliefs to kill the cattle or to eat the meat. As a result, calves and cows that cannot be fed are allowed to perish: an appalling waste of animal products.

In the countries of the southern Far East, as far north as the valley of the Yangtze River in China, the zebu and the water buffalo are the only two types that can stand the climate. In China the great density of population necessitates the fullest possible use of the land for the production of crops suitable for direct human consumption; therefore few cattle are kept, and those few are used mostly for draft purposes. The Chinese are not restrained by religious scruples from keeping the cattle population within reasonable bounds

In Africa, the principal cattle lands are the savannas and tropical steppes of the Sudan and the grasslands of the east African plateaus. The majority of the cattle there also belong to the humpbacked species. Among many Negro tribes cattle are kept only for purposes of social prestige. Their milk is used extensively, but they are considered too precious to be eaten except on occasions of extraordinary importance. Over large areas of Africa, especially in the lowlands, stock raising is impossible on account of the prevalence of the dreaded tsetse fly which is the bearer of sleeping sickness, a disease deadly to cattle as well as to man.

In tropical South America cattle raising is subject to the same difficulties as are encountered elsewhere in the warmer regions of the earth. Animals of a rather inferior taurine type are produced extensively in the llanos or savannas of Venezuela and Colombia, but there, as in central Brazil, the aggregate financial returns are still relatively low. Other regions, toward the margins of the tropics, produce healthy cattle and good beef.

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Chapter Nine

THE REGIONS OF DRY TROPICAL CLIMATES

A CLIMATE MAY BE CLASSIFIED AS *dry* wherever the rainfall is not sufficient to support tree growth on the uplands. Although other factors may contribute to the absence of trees, aridity is the fundamental cause for the existence of most of the treeless areas in the warm climates. As pointed out in preceding chapters, the equatorial belt is rainy. On each side of this rainy zone, in latitudes roughly 20° to 30° north and south of the equator, lie belts where little rain falls. (See World Map of Climatic Regions at end of book.) These dry belts, crossed by the Tropics of Cancer and Capricorn, are often referred to as the tropical desert areas. The middle portions are extremely dry, in places almost rainless, and are bordered by semiarid belts which mark the transition to the more humid climates on either side. Equatorward lie the subhumid tropical savanna areas, while poleward lie mostly areas of subhumid Mediterranean climate. On the basis of winter temperatures, considerable portions of the poleward sections of the Dry Tropical Climates (4 and 5 on map at end of book) should have been classified with the areas of Subtropical climate. These differences in temperature, however, are subordinate in comparison to the main criterion: a high degree of aridity throughout all or nearly all of the year.

From a causal point of view, the semiarid to arid conditions near the Tropics of Cancer and Capricorn and the heavy rains in the equatorial regions are associated with differences in atmospheric pressure. While the equatorial belt is characterized by comparatively low pressure, ascending air, and heavy rainfall, in the high-pressure belt along the Tropics the air generally is descending and little rain falls.

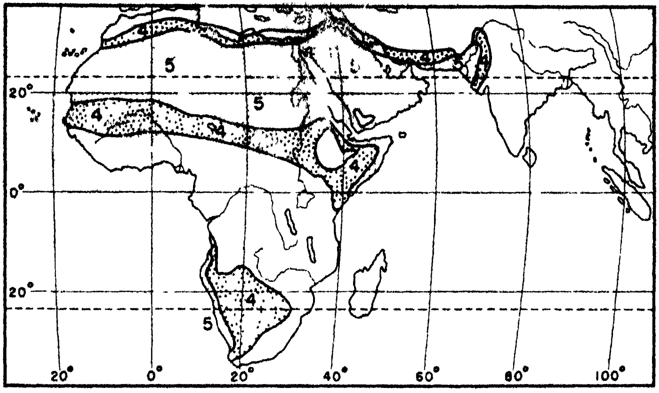
Where the rainfall in the Tropics suffices to support only bunch grasses and thorny bush, sometimes interspersed with a few scattered, very hardy, drought-resisting trees, the climate is classified as semiarid. Where the rainfall is so slight that vegetation is sparse or wanting, where the annuals are dormant most of the time and the landscape is characteristically brown rather than green, there is the desert, a product of the arid type of climate. Although the amount of annual rainfall is not a reliable criterion, since magnitude of potential evaporation should also be taken into account, it may be said that the deserts of the tropical zone generally have less than 15 inches of rain per year, whereas the warm semiarid lands receive an average annual rainfall of 15 to 35 inches. The rainfall in the desert is slight and irregular and the landscape acquires a greenish tinge only for brief periods following infrequent showers. In semiarid lands, where the rainfall is somewhat heavier, the short grass or scattered shrub vegetation presents a green landscape regularly for a few months each year.

Inasmuch as low rainfall is the critical factor in arid and semiarid lands in both the low and the middle latitudes, it seems advisable to use a nomenclature that clearly reveals this fact. The term *desert* is universally used as a term for dry lands in all latitudes. It seems justifiable to use the term *steppe* in similar manner for semiarid lands, whether they occur in middle or in low latitudes.

The Tropical Steppes

The largest areas of warm, semiarid lands are in Africa, where the "Sahel" of Tunisia, Algeria, and Morocco, the Sudanese Sah[illegible] and the Kalahari steppes are prominent examples of this type. The Sudan steppe lands extend entirely across the continent, from Senegambia to Somaliland. (See Illus. above.) Although varying considerably in their aspects from place to place, they possess the common characteristic of a native flora of bunch grasses, scattered thorny bush or other xerophytic plants, while along the permanent and intermittent water courses there are some trees. Southward, the Sudan steppe merges imperceptibly into the tropical savanna lands; northward, it merges into the desert. The steppe lands of French North Africa and Libya continue eastward into the steppes of Mesopotamia, Persia, and Baluchistan. Parts of these areas experience some cool to cold weather during the winter months. The Kalahari ranges from a pure grass steppe in the southern section to mixed acacia, bush, and grass in the central part. Westward it merges into true desert, the Namib, while northward it merges into the deciduous forest lands of Angola and northern Rhodesia.

In Australia, the semiarid belt borders the arid interior, being the transition zone between the rainier coastal strips and the almost rainless interior. In South America, the most extensive area of warm, semiarid land lies in eastern Brazil, where considerable portions of the northeastern states, such as Piauí, Ceará, Pernambuco, and Bahia suffer from insufficient rainfall. Smaller areas occur in northern Argentina and southern Bolivia—the Gran Chaco—and in southwestern Ecuador.

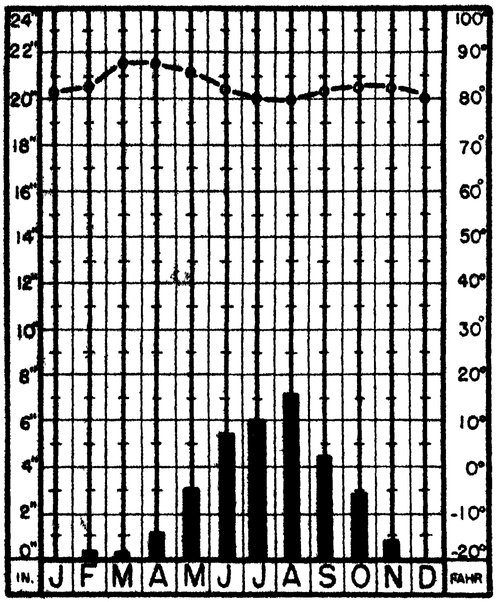


Regions of dry tropical climate in Africa and adjacent parts of Asia. 4. Tropical steppe climate. 5. Warm desert climate.

In North America the areas of warm, semiarid steppes include parts of Lower California and of the Plateau of Mexico. (See World Map of Climatic Regions at end of book.)

Since the larger areas of warm, semiarid steppes are in Africa and Australia, the discussion which follows is based on conditions there. In North and South America conditions are broadly similar but differ in detail.

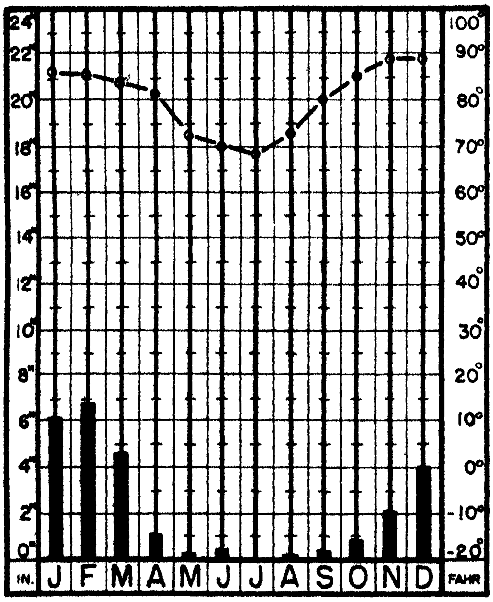
General characteristics. The most prominent features of the warm, semiarid type of climate are the low annual rainfall, usually less than 35 inches and often less than 25, and its distinctly seasonal distribution (see Illus. below). The dry season lasts from six to nine months, with some months that are virtually rainless. Except in the areas poleward of the deserts, the rainy season is generally associated with the high-sun period of the year, while the drought is most intense during the low-sun period. The tropical savannas have a similar seasonal distribution of precipitation, with summer rains and winter drought. The difference between steppe and savanna is one of degree rather than of kind.



Tropical steppe. Average temperature and precipitation, Hillet Doleib, near Malakal, Anglo-Egyptian Sudan. Altitude 1,283 feet, total precipitation 31 inches.

Temperatures, on the whole, show a greater seasonal rhythm than in any of the more humid climates thus far discussed. This is due chiefly to the greater distances from the equator at which the dry steppe lands occur, although the greater dryness of the air is an important contributing cause. The hottest season of the year usually occurs during the high-sun season, just before the rains begin. There is but little cloudiness to reduce the intensity of the sunlight, and high temperatures during the daytime are the logical result. At night, in the absence of clouds to retard the escape of heat, radiation is rapid and relatively low temperatures usually ensue.

During the high-sun periods the warm semiarid climates are characterized by variable winds and light rains, mostly of the convectional type. The rains are rarely of long duration, although they may be heavy while they last. In the northern Sudan, northeasterly winds prevail during the dry season, blowing from the high-pressure area of interior northern Africa toward the "low" which lies along the Guinea coast, a strong local manifestation of the trade winds. These dry winds give rise to a hazy, dusty atmospheric condition, but, because they promote evaporation, they feel cool and bring a sense of relief from the oppressive moist heat of the rainier period. These northeasterlies, known as the *harmattan*, are sometimes referred to as "the doctor" because of their bracing or energizing influence upon human activity. This in-



Tropical steppe. Average temperature and precipitation, Daly Waters, Northern Territory, Australia. Altitude 633 feet, total precipitation 26 inches.

fluence, with equally favorable results, extends southward into the more humid areas.

The shifting of the winds from the calms and variables of the rainy season to the steady winds of trade-wind type during the dry season is common for all the warm semiarid regions. These regions are in general characterized by fairly well defined wind shifts and accompanying moderate temperature changes. Nevertheless, although the weather conditions are sufficiently varied to prevent the enervating monotony of the humid tropical type of climate, they can hardly be called pleasant and agreeable. High daytime temperatures, brilliant sunshine rarely cloud-obscured, hazy atmosphere laden with dust, dry parching winds, and little rain constitute a fair résumé of the prevailing weather of the semiarid tropical lands.

Native vegetation and animal life. The ground zone of vegetation is low, consisting of grasses and low xerophytic shrubs, either or both, with bare ground showing conspicuously in places. (See pp. 86-88.) The grasses are mostly of the bunchy types, rather coarse stemmed, although in some areas fine short species thrive, providing forage for numbers of grazing wild animals such as gazelles and antelopes. The ground zone of vegetation is surmounted in many places by scattered bush or even occasional small clumps of low, thorny trees. The shrubs are characteristically thorny, and the term "cat's claw," often used in describing them, is truly expressive. In general the leaves are small and leathery, so constructed as to conserve moisture and at the same time carry on the processes of transpiration and tissue building. The root systems are shallow but extensive, thus being adapted for rapid absorption of such soil moisture as becomes available after the showery rains. On the uplands the landscape presents broad views when observed from low hills or other eminences. Although the water courses are dry most of the time, tree growth and thorny bush along them are plentiful because of the supply of ground water. These strips of bush and forest may be junglelike in their density. The bark of the trees usually is thick, the leaves are narrow, and spines and thorns are numerous. The wood generally is hard, with twisted or gnarly structure, which makes it difficult to split or saw the logs into boards.

In most places the warm semiarid steppes have some sort of timber well suited for such simple construction purposes as building huts for people and corrals for livestock. Acacias and various tree cacti are common and useful for such purposes. The fuel needs are not great, and the supply of tree and bush is usually ample. Grazing is the most economic use that can be made of the land, the type of grazing being dependent upon the quality of feed available. Edible shrubs are the chief forms of vegetation, and since they are not abundant, only goats and camels prove successful. On the other hand, where grasses abound, together with the more palatable species of shrub and bush, sheep are favored. The old adage, "goats on the lean lands, sheep on the fat lands," is quite literally fulfilled in man's use of dry steppe lands for grazing purposes.

Soils. As the rainfall in regions of warm semiarid climate is insufficient to produce heavy leaching, the soils are generally rich in lime and other minerals, and therefore belong to the pedocalic group. The color ranges from chestnut brown to gray as desert conditions are approached. In some areas, where grasses are abundant, soils so dark as to resemble chernozems have been found. Where leaching is slight, there is a tendency for sodium salts to become concentrated in the upper parts of the profiles of semiarid soils, this tendency being more pronounced as aridity increases. Where, owing to topography, the ground-water level is near the surface, saline or alkaline soils may occur.

Where rainfall is so low that near-desert conditions prevail, the soils are generally immature because of incomplete chemical weathering and unfavorable conditions for organic activity. The colors are usually grayish, often light. Such soils are rich in mineral constituents—in many cases excessively so, with resultant alkali conditions—but they are deficient in humus.

On the whole, however, the soils of the steppes average fairly high in potential productivity; their mineral content is ample, their structure is stable, and they are easily tilled. The problem of agricultural production is one of water supply rather than of soil fertility.

Agricultural practices and possibilities. The warm semiarid lands are natural grazing grounds. The native animal life is either fleet footed or fleet winged and thus is able to move rapidly and over long distances to obtain water. The exceptions—that is, those species that are not swift of foot or wing—are well protected by thick skin or scales, so that existence with little water is possible. The warm steppe is the land of the antelope family, which is able to subsist on the moisture found in grass and in leathery leafed shrubs when other water supplies fail. In southern Africa part of it is known as the *veld*, which once harbored multitudes of gembok, wildebeest, and hartebeest. Insect life is abundant. The warm semiarid lands of Africa, Australia, and of northern Argentina are noted as being the breeding places for hordes of locusts, which swarm into more humid sections during dry years, causing heavy damage to crops and native vegetation.

Wherever man attempts to develop economic pursuits in the warm semiarid lands, he must either adapt himself to the climate and native plant and animal life or he must overcome whatever handicaps are encountered. In the areas where moisture is sufficient, or where it is provided through irrigation, some crops can be grown, as, for example, sorghums, millets, and barley. Thus, grain for food and for feed can be provided. In general, however, there is but little grain farming in the warm, dry lands of the world; some form of herding is the dominant economic pursuit, and most people are nomads. Small-scale cultivation can produce a valuable harvest only where conditions permit relatively large yields per acre, and these are not possible when rainfall is deficient. In some places people carry on quite well during periods of relatively heavy rains; then when a period of drought follows, with attendant sparseness of grass and failure of crops, migration becomes necessary. Whole clans with their herds and flocks go on the move—the centuries-old trek for water and grass.

Extensive development of the semiarid tropical lands must await the time when the increased population of the world will have utilized the humid savannas and when man will have to be satisfied with the less desirable areas. Then choice will have to be made between the dense jungle and the rain forest of the equatorial belt on the one hand and the semiarid steppes on the other. From the standpoint of middle-latitude demands, the chances favor the warm wet lands because their products cannot be duplicated in the cooler lands, whereas the animal products of the warm semiarid countries do not differ greatly from those of cooler climes. For example, bananas, coconuts, and cacao, products of the warm humid lands, have no competitors in the northern markets; on the other hand, products of the warm dry lands, such as tropical goats, sheep, and cattle, have no such monopoly, but must meet the direct competition of their kind produced in cooler climates and generally under more favorable conditions as to environment and markets.

The Warm Deserts

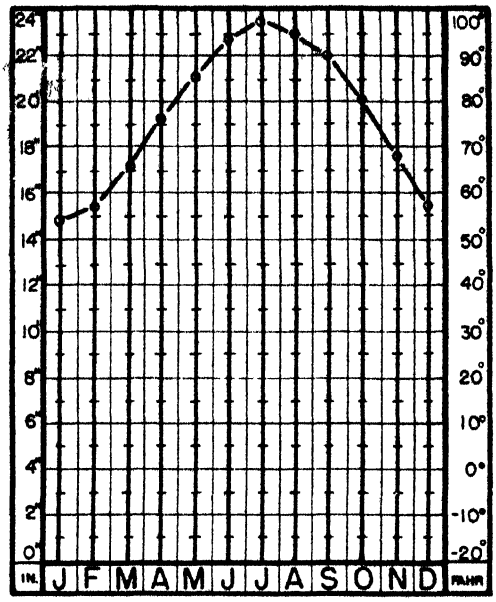
It is estimated that 12 to 15 per cent of the land area of the earth is dry desert. The climate map shows clearly that the largest extent of dry deserts lies in the relatively low latitudes and that most of the great deserts lie in the vicinity of the two tropics. From a climatological point of view we may say that their location is poleward from the tropical semiarid lands and that the deserts constitute a sort of dry divide between the rainy lands of the low latitudes and those of the middle latitudes. (See No. 5 on World Map of Climatic Regions at end of book, and also Illus. p. 143.)

As stated at the outset of this chapter, the term *desert* is not limited to lands wholly devoid of vegetation. It includes also areas where the vegetation is dormant most of the time and where the landscape is characteristically brown, although occasionally rains may turn it into brilliant green and cause it to become flower-besprinkled for short periods. The true deserts are rocky, gravelly, or sandy wastes, but as ordinarily used the term is somewhat more inclusive.

General characteristics. The rainfall in the desert is irregular as to occurrence and torrential as to volume. At a given place, months, even years, may elapse during which no rain whatever falls. Occasionally, however, sufficient moisture may be in the air so that, under the influence of rapidly ascending convectional currents, thunder clouds may develop and heavy showers of rain result. Since life in the desert is adapted to aridity, great damage is sometimes done by such rains. A place which has had no rain for several years may receive three or four inches within a few hours. For a short time rain may fall in torrents, producing a veritable "cloudburst" which quickly inundates the flat lands, changes dry stream beds into raging water courses, and destroys earth houses in which the natives dwell. The French soldiers stationed in the Sahara have strict orders *never* to camp in the *wadis* (the dry stream channels) because of the danger of sudden catastrophes of this kind. But the rainstorms are short lived. The clouds quickly disappear, brilliant sunshine returns, and soon the landscape again presents the shifting hues of the desert.

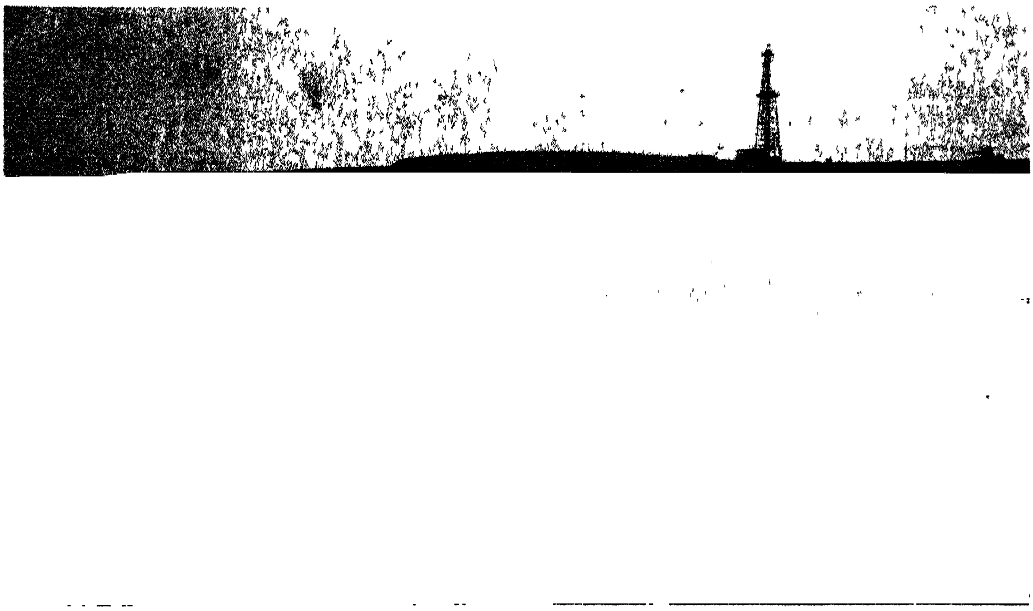
Temperatures and winds are subject to similar fluctuations. The changes in temperature from day to night are great and commonly are as much as 40° or 50°F. In winter, night temperatures may occasionally drop close to the freezing point. This violent daily range is a source of discomfort to man and beast—roast at midday, freeze at midnight. (See Illus. below.)

While the absolute humidity often is not particularly low, the average relative humidity commonly lies between 30 and 50 per cent and during the daytime may drop below 20. The occasional strong winds are perhaps the greatest source of discomfort experienced. These winds, low in moisture, of high temperature, dust and sand laden, cause parched skins and cracked lips for those not hardened to them and discomfort in varying degree to man and beast. The hardships of travelers who encounter severe sandstorms are quite well known, but it is not so generally understood that moderate winds rather than gales are most common in desert areas. The bare rock wastes or hot sands give rise to uneven pressure and unstable conditions in the lower strata of the air. Thus, currents develop and the rapid movement of air near the surface from one place to another often gives rise to variable wind directions.



Tropical desert. Diagram of temperature and precipitation for In-Salah, Sahara. Altitude 1,080 feet, no precipitation recorded.

Where the desert reaches its full development as an expanse of bare rock (*hammada*) or pebble pavement ("reg"), or in the case where it is slightly friendlier to man as in the areas of sand dunes ("erg"), it always has associated with it the lure of ever-changing landscape. Thus, the desert has been the place where man could experience Nature's unbridled forces, and from it have come some of the most eloquent portrayals of landscape ever penned, among them the following:



Courtesy Standard Oil Co., N. Y

Sand dunes in the desert of Saudi Arabia. Note oil derrick and tanks in background.

"The Sahara, though frequently tawny in spots, runs through the whole gamut of colors. In the early morning it is a dirty bluish gray, of much the same tone as the refuse from a soda-ash manufactory; but as the sun rises it becomes a dazzling white, like drifted snow, so glaring that the eyes must be protected with tinted glasses. Under certain atmospheric conditions, however, I have seen the outcropping rocks of the *hammada* become as red as the walls of the Grand Canyon. But the desert assumes its loveliest tints with the approach of nightfall, when it gradually changes from white to vivid orange, to blue, to amethyst, to deepest purple. Then when the stars come out, it changes to gray again, an indescribably soft and misty gray, like smoky chiffon over silver tissue." [1]

With minor changes as to detail, this description so vividly given for the Sahara would fit any of the other great deserts—the Arabian, the Thar, the great desert of Australia, the Namib, or the Atacama. The centers of these areas are mostly barren wastes, but from those centers outward there is a gradual change from bareness of vegetation, through scattered bush and shrub, to the more richly clothed grass and tree steppes. The heart of the desert, the true wasteland, is without human permanent occupance; it is a place to be traversed if need be, but not to be lived in.

Utilization of desert lands. Human occupance of the land, except in oases, begins where grass meets sand or rock waste —the edge of the true desert. This edge is a transition zone of varying width where some verdure is found but where the rainfall is so scarce that the classification of desert still holds true. The transition zone advances from the desert in dry years and recedes when years are wetter than normal. There, at the edge of the desert, man pushes ahead with the rains and retreats with their absence. This is the zone of mobility. When moisture comes, plants flourish, and man prospers because flocks of goats or sheep can make use of the pasturage. When rains fail, grass fails, and man and his flocks must move on to other pastures. The edge of the desert is the realm of the nomad.

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[1] Powell, E. Alexander, *In Barbary*, D. Appleton-Century Company, New York, 1926.

The native vegetation. The native plants at the desert's edge are highly specialized to conserve and utilize moisture when it is available. This specialization is observable in the root systems, in the leaf and stem structure, and in the distribution of the plants. Most perennials have roots that may penetrate scores of feet downward in the search for water. Other root systems are shallow and intricate, and when the occasional dashing rains come, this intricate network of roots springs into action and literally drinks up the water before it has time to escape by evaporation into the atmosphere. Plants, such as the cacti, have developed thick roots and fleshy stems and leaves by means of which they conserve the needed moisture. A large percentage of the plants are equipped with leaves and stems which have glossy skins, sometimes underlain with corklike zones; such structures retard evaporation and cause a little water to last a long time in supporting the circulation of the plant. Furthermore, plants grow far apart, thus allowing more room for the roots of each. These types of vegetation furnish sustenance for pasturage.

Soils. Desert soils rarely develop distinct profiles such as are characteristic of soils in humid areas. In deserts the actual weathering is mainly physical; because of the lack of water, chemical weathering is slow, notwithstanding the high temperatures which prevail in the tropical latitudes. As a result of deflation processes, sands, rather than clays and silts, are dominant, finer materials having been carried by winds to surrounding, more humid areas. Clayey material is washed together into salt flats (*Selkas*) which often contain high concentrations of various salts. Since the land surface lacks the protection of a continuous vegetative cover, wind erosion is marked; desert pavements, consisting of rock platforms or rock fragments from which the finer materials have been swept away by wind action, are well-known features of deserts. In other cases, areas of shifting sand make up the land. There the landscape takes on a billowy appearance without distinct markers and hence is often referred to as a trackless waste. Camels, because of their remarkable ability to cross such areas, have aptly been called "ships of the desert."

Desert soils are commonly gray, but red soils also occur in a number of places, especially where the bedrock consists of red sandstone. The soils of the desert are usually rich in soluble minerals because the light rainfall which occurs results in little or no leaching. In shallow depressions, where water may gather following heavy showers, the soils are often so crusted with mineral salts that they are unproductive even under irrigation. Excess of sodium salts in desert soils is common and is responsible for many of the "alkali" soils encountered in desert areas.

In dry lands agricultural productivity is dependent chiefly upon stability of the soil and available moisture. Most desert soils are sufficiently rich in mineral content, but they are subject to wind erosion and are deficient in moisture. Soil stability and water supply are the requisites for dependable production.

Agricultural industries. There are two phases of desert agriculture: grazing livestock, and, in the scattered oases, crop farming. Local oases occur where there are wells or springs or where shallow underground waters of the wadis sustain plant growth. In some sandy lowlands the ground water is so near the surface that it may be made available for plants if a few feet of the dry surface sand are removed. In such manner true sunken gardens are produced, and the principal work of cultivation is to keep the inblowing sands from covering and smothering the vegetation, as in the Souf region of southern Algeria, east of Touggourt. The lowlands along the lower course of the Nile, where lands were formerly irrigated by overflow but are now watered largely by directing ditches, is one form of oasis, perhaps the most extensive as well as the most unusual type.

Date production. The principal commercial crop of the desert is the date. The date palm is perhaps the oldest known cultivated fruit tree in the world. The early records of the Sumerian and Babylonian peoples in the Tigris and Euphrates valleys show that it was widely tended by farmers several thousand years before Christ. The technical name of the date palm is *Phoenix dactylifera*. Its optimum habitat is in warm lands with practically no rain, but where irrigation is possible or where ground water is available. It is a tree of the oasis rather than of the waterless desert. It is probable that in Assyrian times some wise observer discovered the art of artificially pollenizing the date palm and thus achieved one of the earliest advances in scientific agriculture, an achievement which has continued to be of great importance ever since.

The Arabs introduced the palm and the art of its cultivation into Spain. The Spanish missionaries brought the seed with them to Mexico and California and under favorable conditions produced dates successfully, thus initiating a practice which has developed into a sizable modern industry in the Coachella Valley of southern California.

The centers of large-scale production of dates have, however, remained in the East. In French West Africa dates are essential for the successful operation of the caravan routes. They make up the principal crop of the scattered oases and constitute the chief cash crop available for commercial purposes. In Algeria, Biskra has become an important date market. Also Tunisia, and especially Egypt, are important producers. The lands around the Persian Gulf and Gulf of Oman constitute the major date-producing center of the world. In Oman the fruit is raised by irrigation along the coastal valleys in such abundance that it has become the leading export commodity. In Iraq, date gardens are found in the fertile irrigated lowland along the Tigris and Euphrates rivers. The date is valuable as a local food and as a cash crop. Bagdad and Basra are the chief export centers for the Mesopotamian and adjacent Persian areas.

The date has long been recognized as essential in the scheme of desert agriculture. It is claimed that Mohammed was careful to teach this lesson to his followers, and that at one time he said to them: "Be good to your Aunt, the Palm, for she is made of the same clay that you are." They have been watchful ever since, even in war, no matter how severe the conflict, that the date palm should not be injured. Thus does the desert dweller pay homage to his staff of life, the date palm!

Herding. The native animal life of the desert shows specialization in conservation of water similar to that of the plants. Animals are either slow moving, thick skinned and plated with bony armor, and furnished with extra water pouches, or they are so swift moving that they may quickly migrate from dearth of water to where it is plentiful. The horned toad and the Gila monster are examples of the former type, while the gazelle typifies the latter.

Among domestic animals the camel is the classic example of adaptation to the desert. He can eat coarse feed because he has lips equipped with skin that is nearly as hard and tough as the leather used for shoe soles; with those lips he can browse thorny bush and, in finger-like fashion, reach into crevices in the rocks for choice bits growing there. When he encounters a storm, he can constrict his nostrils to small-size apertures wherein a sieve of hairs strains out sand and dust from the air he breathes. He has eyelids equipped with double shutters to protect the orbs from the driven sands. The African camel has soft feet with wide surfaces that prevent sinking into the sand. His stomach is adapted to storing extra water for a period of several days. And for long journeys, when feedstuffs may be scarce, he has the humps on his back which serve as an extra feed supply upon which he may draw for bodily energy—a sort of extra gasoline tank for the animated desert motor! Is it any wonder that the camel has, through the ages, been man's chief reliance for transport over arid and semiarid lands? (See Illus. below.)

Today, however, the camel is in process of being displaced by the airplane and the automobile. For example, it is possible today to buy a bus ticket in Colomb-Bechar in Southern Algeria, and five and a half days later arrive on the other side of the Sahara desert, in Gao, a city located east of Timbuctu. Other bus lines connect such oases as Ouargla, El Golea, In-Salah, and Ghat, while in the winter season there is another Trans-Saharian bus line from Alger to Zinder, just north of the northern boundary of Nigeria. Several airlines regularly cross the Sahara.

The flocks which constitute the productive basis of wealth are the sheep and goats. In most desert areas, cattle do not prosper; the herbage is neither plentiful nor succulent enough for their needs. Sheep and goats have developed resistance to scarcity of water and tolerance for rough feeds far beyond that of cattle, therefore they accompany man farther into the lands of hardship and furnish sustenance where without them he could not survive.

Most land that is good for nothing else will, without man's intervention, grow some kind of plant that some kind of animal will eat. Since that is true at the edge of the desert, the herdsman is at home there. On the comparatively fat land he raises sheep, on the leaner lands, he must rely on animals that will utilize feeds so coarse that the sheep spurn them. There, the goat is the chosen one upon which man must depend. We laugh at the goat for his great and varied dietary habits, but these are prized abilities in the land of little rain and scant, coarse herbage (see Illus. p. 152).

The animal industries consist of production of animals (1) for power and transport —camels, horses, and donkeys—and (2)

Courtesy Standard Oil Co., N. Y.

Caravan of camels Arabian Desert Oiled road tends to hold sand in roadbed Note oil tanks in distance for food, clothing, and shelter—sheep and goats. At the edge of the desert, donkeys outnumber horses and goats outnumber sheep. The camel is the means of long-distance transport; the donkey is the "small car" for short hauls; the horse is the symbol of aristocracy, the Rolls-Royce of the desert.

Desert mode of life. The dweller on the margin of the desert is of necessity a nomad—he has no choice in the matter. Rains are uncertain as to time and place of occurrence; intervals between rains may be weeks, months, or even years. When the rains do come, the dormant vegetation promptly responds; bush and grass quicken into green life for a while, only to lapse again into dull gray and brown when the refreshing influence of the moisture wanes. In order to utilize the vegetation, animals must be able to browse short grass, brush, and shrub, as occasion offers. For this reason the desert dweller must build on the basis of grazing.

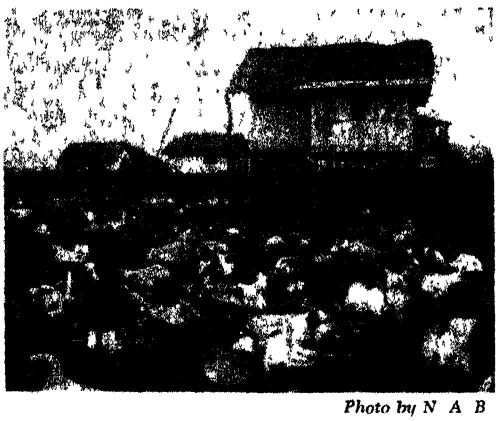

Photo by N A B

Goat magnate's home. These goats pasture in adjacent thorny bush slope lands. They are turned loose in the morning to seek pasturage and of their own volition return to their owner's pens before the sun sets.

People at the desert's edge are rovers not because they are different in inherent qualities from other people; on the contrary, they are quite similar. They are nomads because of the inborn will to live; if they would live, they must roam with the flocks that feed them. The laborer at the blast furnace, the farmer in his field, and the salesman at the counter carry on their duties in their different lines for the same reason—that they may live and enjoy the available comforts of life. On the desert's edge the nomad follows the shifting rain belt, adapts himself to the changing environment, and overcomes the obstacles involved in the struggle, proud in his own achievement and perhaps a bit scornful at the ease that he considers to be the lot of the sedentary dweller.

The differentiation of labor is sharp: men are the herdsmen and the fighters; women till the soil at times when such occupation is possible, and they carry on the home industry. The flocks give wool and hides; these are the chief bases of the household arts. Tannin-producing plants make possible one of the most skilled arts in the world, the making of Morocco leather. The fine and strong fleece of sheep and goats is the raw material for making shawls and rugs of world-wide fame. The women, working patiently with hand spindles and looms, weave shawls and rugs noted for their durability and also for their unexcelled artistic beauty. The rugs thus made are objects useful in the domestic life of the nomads; they serve as floor covering, over the desert sands, and as couches and beds, taking the place of both mattress and cover. They combine utility with high value, little bulk, and ready mobility—desirable qualities for those who must always be ready to move on.

The general tendency is for the desert dwellers to raid the cultivated agriculture at the desert's edge. There are grown the grain and fruit that the nomads in their own habitat lack or can produce only in small quantities at cost of much labor. If the raids are prevented, as is the case when organized government is established, then at the desert's edge there become established market places where exchange of products is carried on, where the nomad and the farmer can trade to the advantage of both. These markets naturally flourish best along the major trade routes, and the cities which develop there become outfitting centers for the caravans which cross the desert expanses. Such cities are picturesque in their variety of products and of peoples. There the market places exhibit dates and grains, barley and melons, hides and skins, and on the streets are seen the keen-eyed traders, the sturdy farmers, and the dashing Bedouins.

Where people cannot depend on remaining in one place, individual property values cannot center upon land, and so flocks are usually the criteria of wealth. Real estate, as such, does not and cannot permanently belong to any individual but is often held to be the property of the tribe. Thus, the idea of property rights is one of continual vigilance, constant mobilization for defense or attack. The land belongs, for the time being, to the tribe that holds it and, if necessary, fights successfully to keep it. Barley, the product of most favored spots is the common breadstuff. The desert nomad camps by the field because he must keep marauders away if he would eat bread. In times of scarcity he exemplifies the axiom, "Self-preservation is the first law of nature." Since the democratic ideal of share and share alike would give none enough to live, he survives by taking all he can—those not successful in taking, perish.

The occupations of men—herding, hunting, fighting—are dangerous, and hence mortality is high. Thus, there is a surplus of women in a social group wherein there is no opportunity of employment as stenographer, clerk, nurse, teacher, social secretary, or any of the other numerous openings that are available for women in the more advanced civilized communities. If women would survive they must be attached to households, and so polygamy results, an adaptation to the conditions under which existence must be maintained.

On the whole, the desert's edge is a taskmaster with sharp requirements for those who survive. It produces a people strong, fearless, and virile. These are the characteristics most conducive to success under the conditions which prevail where desert brown and grass green intertwine, because there man must be able to move quickly, to run and to ride; in this contest, lean men survive because fat men can neither run nor fight.

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Chapter Ten

THE REGIONS OF MEDITERRANEAN CLIMATE AND THEIR PRODUCTS

POLEWARD FROM THE TROPICAL CLImates are areas where most of the months are warm but where there is a short winter season, cool and with occasional frosts. Because of the lower average annual temperatures and the existence of a cool season, these climates are called *subtropical* rather than tropical.

In the subtropical regions temperatures show a marked seasonal rhythm, and hence we find the terms *winter* and *summer* in common use. In this discussion, subtropical climates are defined on the basis of the average temperature of the coldest month—which is more than 43°F. (6°C.) but less than 65°F. (18°C.), with possibility of occurrence of frost. Whereas the cold limits of these areas may have frost-danger periods up to four months in length, the warm limits in some years may not have any frosts at all. In other words, in the different parts of the subtropical belt the annual frost-free period, often called the growing season, varies in length from nearly a full year to slightly more than eight months.

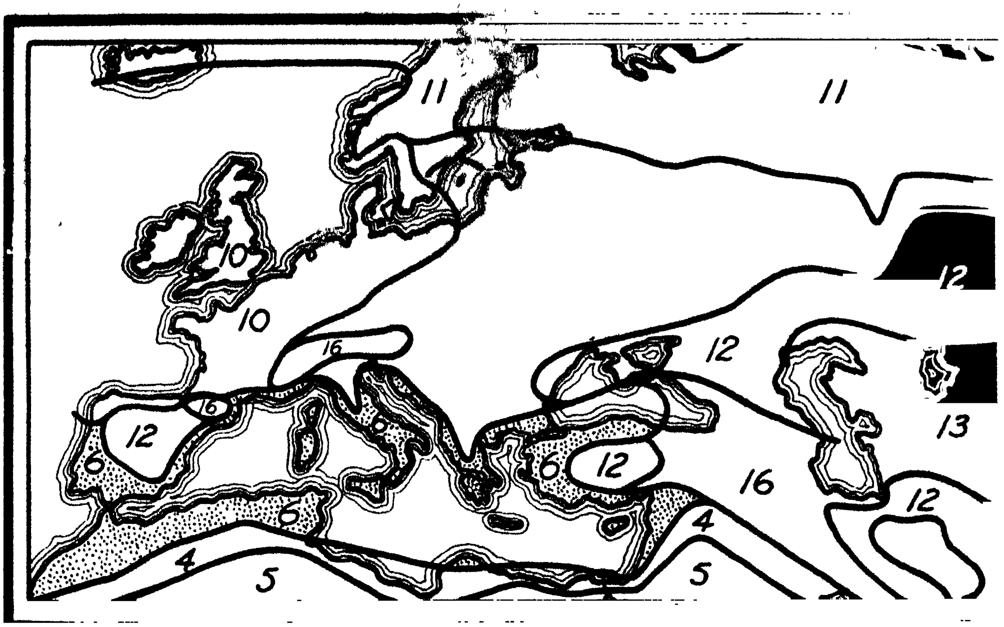
There are pronounced differences between subtropical climates of the eastern and the western parts of the continents. In the subtropical belt, particularly in winter, the air masses bring rather stable oceanic temperatures to west coasts and variable continental temperatures to east coasts. Thus Los Angeles, California, has a difference of only 16° between the mean temperatures of the coldest and warmest months (55°F. in January, 71°F. in August), while Charleston, South Carolina has a range of 31 degrees (50°F. in January, 81°F. in July). Similarly, Madeira, in the east Atlantic, has a range of 13 degrees (59°F. in January, 72°F. in August), while Hongkong, China, has a range of 23 degrees (59°F. in February, 82°F. in July). As a result, the mild winters of the western subtropical climates extend farther poleward than do those of the east coast subtropical climates.

Rainfall contrasts between west and east coasts are even more striking. The west has a rainless summer, while the east has rainfall at all seasons or, in the case of southern China, a pronounced summer monsoon maximum of rainfall. Los Angeles has a period of about 5 months, from early May to late September, with no rainfall whatsoever in most years. The driest month at Charleston, South Carolina, has 1.8 inches of rainfall on the average. The storms from the Pacific pass to the north of California in summer, and particularly during June, July, and August fairly strong and constant southeast winds blow over the adjacent ocean. As these winds are parallel to the shore, they do not cause precipitation. Besides, they constitute the beginning of the northeast trade-wind system of the North Pacific, and the trade winds, blowing from higher to lower latitudes, or from cooler to warmer areas, generally cause dry conditions. In southeastern United States the effects from storms farther north are felt even during the summer months, while also part of the northeast trade winds of the West Indies are deflected northwestward, toward the southeastern coasts of the United States, owing to prevailing low pressures in the interior. This reversal of direction results in some cooling and precipitation, especially after the air masses reach the coastal area.

In the Mediterranean region, which is more typical than California, the roots of the trade-wind system prevail in the summertime with rather constant northwest, north, and northeast winds, while during the winter months the weather is governed by locally developed lows and by air masses entering the Mediterranean through France and southern Spain as part of the northern cyclonic circulation. The summer winds cause dry weather, except where they hit mountain ranges, while the winter circulation causes precipitation. The west coast climate is called *summer-dry subtropical* or *Mediterranean* climate, while the eastern type is called *humid subtropical* or, in the United States, the *cotton-belt climate.*

Distribution and Characteristics of the Mediterranean Climate

The Mediterranean type of climate reaches its most extensive development along the margins of the Mediterranean Sea, from southern Portugal and Spain to Palestine—an east-west stretch of over 2,000 miles (Illus. above). Other regions of the world where similar climatic conditions exist are smaller but nevertheless important seats of human activity. Such regions exist in southern Africa, southern Australia, central Chile, and California. In California the area with Mediterranean climate embraces the southern coastal region and the major part of the Valley of California. In South America this climate is typical for the central part of Chile, between the 32nd and 37th parallels, a strip of land about 500 miles long and 200 miles



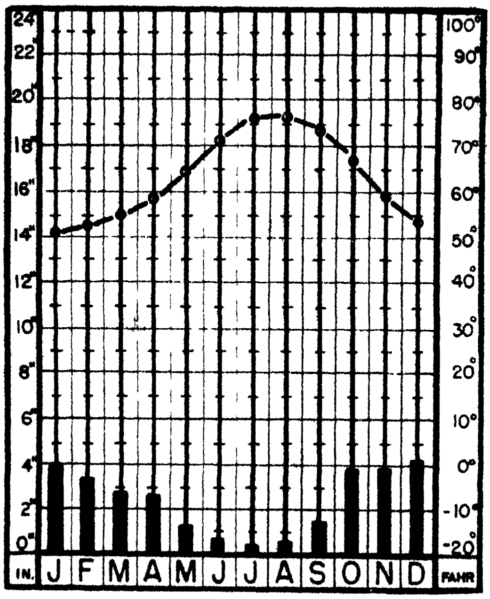
Regions of Mediterranean climate around the Mediterranean Sea (No. 6).

wide. However, within the area the Andean slopes, constituting a belt with a width of about 50 miles, are of little agricultural significance. Also the Coast Range, with an average width of 20 to 25 miles is of limited use. Thus the economically important part of the area is restricted to the central valley. Even here spurs of the Andes and of the Coastal Range further limit the amount of level land suitable for agriculture. Nevertheless, this region, due to early occupation and irrigation is the most important part of Chile. In Africa the region with Mediterranean climate is a small area near Capetown; in Australia it embraces the coastal regions near Perth, Western Australia, and near Adelaide and Port Augusta, South Australia, as well as a portion of Victoria. (See World Map of Climatic Regions.)

Rainfall and temperature. The amount of annual rainfall differs considerably from region to region, but for the most part it is about 25 inches or less. On the whole, rainfall decreases from the poleward margins which adjoin more humid lands toward the warm deserts of lower latitudes. Thus San Diego, California, has only 10 inches of rainfall a year, while San Francisco, 350 miles farther north, has 22 inches; Jerusalem has 10 inches less rain than Rome, 1,000 miles farther north. The rainfall, therefore, approaches humid conditions at one margin and arid conditions at the other. The distinctive feature common to all areas of Mediterranean climate is the rainy winter and dry summer. Palermo, on the island of Sicily, southern Italy, has a total annual rainfall which is not particularly large and a pronounced dry season in June, July, and August (Illus. right).

In temperatures, too, differences are pronounced within the areas of Mediterranean climate. Poleward and inland from the coasts, frosts are more frequent and severe than equatorward and seaward. Differences in altitude also are important: as elevation increases, temperature falls. In the Mediterranean area many of the mountains are so high, and temperatures as a result are reduced so much, that they cannot be considered as having a Mediterranean climate. Thus, much of the Apennines Mountains, particularly the high Abruzzi, the Sierra Nevada, the Dalmatian Mountains, the Pindus chains of Albania and Greece, or the Atlas Mountains of North Africa have climatic conditions which differ greatly from those in the adjacent lowlands. Natural vegetation, soils, and crops also differ considerably.

These mountain barriers often afford protection from cold winds, thus accentuating the Mediterranean character of the areas at their foot. The Alps and Caucasus, for example, shut out effectively the cold air masses that in winter often lie over southeastern and central Europe. Just south of the mountains are many sheltered spots where winters are mild and sunny and where those in search of health or pleasure may escape the damp, raw, dreary winters of the north. The French and Italian Riviera, the Italian lake region, and the Dalmatian coast, like our own southern California, are such sheltered spots of winter tourism.



Dry subtropical climate. Average temperature and precipitation, Palermo, Sicily Altitude 213 feet, total precipitation 30 inches

Temperatures likewise reflect the fact that the oceans have more stable temperatures than the continents. Thus at Eureka, on the California coast, the warmest month is only 9° warmer than the coldest (47°F. January mean, 56°F. July), while at Redding, 100 miles inland, the difference is 37° (45°F. January mean, 82°F. July). With all their local differences, temperatures do have the common trait of a short cool season and long warm season, and in most places a frostless period lasting more than nine months.

Winds. During the winter, the winds, like the other weather elements, are associated chiefly with the masses of marine air that move in from the west. In California, southerly winds, often with rain, predominate as an air mass approaches the coast. As the front of the mass passes, the wind may be gusty and variable, followed by a northerly wind usually accompanied by clear, cooler weather. This sequence of winds, often including a period of calm, may have innumerable variations. The frequency and duration of storms is greatest toward the poleward limits of the subtropical climates; some of the storms miss the equatorward portions of Mediterranean areas, and those that reach there may be of brief duration.

Occasionally, a mass of cold, dry continental air, with high pressure, may encroach upon the area. Sudden influxes of cold winds in the winter half of the year are notorious features of Mediterranean areas. In central France a cold wind, known as the *mistral,* occasionally sweeps violently southward to the Mediterranean seacoast through the natural corridor of the Rhone Valley. A similar wind, the *bora,* descends violently through the gap between the East Alps and the Dinaric Alps into northern Italy and the Adriatic. In the days when navigation depended upon small vessels using sails, the mistral and bora were dreaded by navigators.

Hot, dry winds sometimes blow into the areas of Mediterranean climate from the deserts that lie equatorward. For example, such winds may carry parching desert air and clouds of dust from the Sahara desert northward across the Mediterranean to southern Europe. In Sicily and southern Italy this wind is known as the *sirocco;* in Spain, the *leveche;* in north Africa and Syria, the *simoon;* in southern California, the *Santa Ana.* The approach of the sirocco is heralded by a haze over the southern horizon; the haze gradually overspreads the sky, and the storm breaks with a burst of wind, dust, and sand, lashing the sea to fury. The relative humidity may drop to as low as 10 per cent, and the dryness may ruin the crops of olives, vines, and other fruits if the storm comes during blossom time. The sirocco may last a few hours or for two or three days.

The renowned colorful sunsets of Mediterranean areas are the result of fine dust blown high into the air during the long dry summers. The coloring is most striking where the dust is very fine, as in the volcanic areas of Italy. The Mediterranean Sea serves as a great mirror to emphasize the sunset colors. The sunsets are a distinct economic asset for tourist agencies.

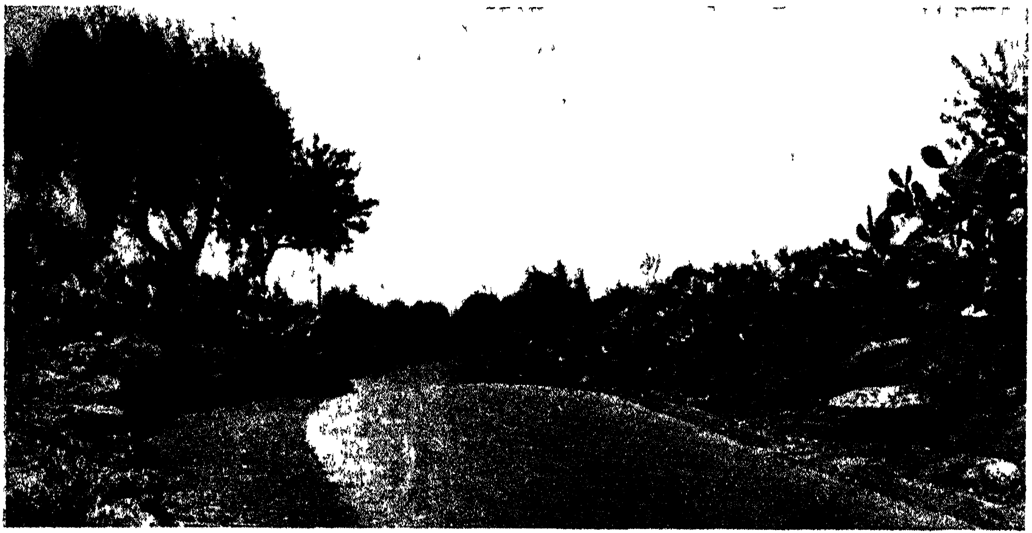
Native vegetation. The totality of climatic conditions is reflected in the native plant cover of an area. The characteristics of the Mediterranean climate that most profoundly affect the vegetation are as follows: (1) rain falls abundantly in the winter half year, especially on exposed slopelands and in the parts of the subtropical belt farthest from the Equator; (2) summer is a period of complete or partial drought; (3) the winters are mild and the summers warm to hot.

The most obvious effect of these climatic conditions is to produce a carpet of brilliant green in winter and of subdued brown to yellow in summer. Many trees and shrubs are evergreens which are able to grow at least during part of the winter season and the spring. During the summer months, however, they are exposed to the burning sun and therefore have developed protective devices against extreme loss of moisture. As a result, most evergreens have hard, leathery leaves, often thickly set with fine hairs further to restrict evaporation. Many deciduous perennials have only very inconspicuous leaves, green stems, and long thorns that take over the leaf function (Illus. below). Annuals can exist only during the rainy season. Grasses and low flowering plants begin to grow after the first rains in the fall, from bulbs or seeds; they bloom in early spring, ripen seeds, and then wither with the advent of the dry, hot summer.

Trees grow widely scattered in the lowlands, except where strips of moist land along streams support "gallery forests." Forests flourish on the higher slopes, especially on those exposed to moisture-bearing winds. The timbers used by the builders of Solomon's Temple and for the construction of boats by the Mediterranean seamen were obtained from such localities. As has been mentioned before, however, many of these higher areas are really areas of mountain climates, located above the typical Mediterranean regions. But as most people live in the lowlands, where timber is not readily obtainable, stone and sun-dried brick have long been the common building materials. This is particularly true of the Mediterranean countries of Europe. In the United States the regions of Mediterranean climate are smaller, and modern transportation facilities make lumber so easily available that wood is generally used for construction purposes.

Much more characteristic and far more widely distributed than the high forest are the thickets or scrub forests, often thorny, which consist of scattered trees and dense masses of shrubs with much undergrowth This type of vegetation, with regional modifications as to species, is common to all areas with this type of climate. The Italian name *macchia* has been accepted to designate it, although the French term, *maquis,* is the form in which the original Italian word was adopted into the English language. In California it is called *chaparral.* The maquis is the source of the bundles of sticks peddled as firewood in the streets of Mediterranean cities and villages, and of manzanita firewood widely used in California Charcoal has long been made out of some of the larger stems and branches.

There is a lower and even more scraggly type of vegetation than the maquis. Inasmuch as the soil may be bare and unprotected by the end of summer, heavy winter



Courtesy U. S Dept of Agriculture

Cacti of the Catania area, Italy Lowest are the garigue, above them the macchia rains may remove much of the soil from steep slopes. These slope lands with their soils are quite extensive and, especially in the Mediterranean countries, support a sparse vegetation made up of small, drought-resistant bush. The Germans call these forms "half-shrubs," an aptly descriptive term because they are half-way between herb and shrub in size. The commonly accepted term is *garigue*, the French term used for this vegetation on the limestone slopes of southern France.

One might at first think that the garigue and the maquis can have little value. However, sheep and goats can thrive on these forms of vegetation. Sheep do quite well where the garigue and maquis are fairly open; where the vegetation is more tangled and coarse, goats are able to find nourishing feed. Through its fodder value, the thorny, inhospitable vegetation contributes directly to the kid slippers and gloves for the ladies of Paris, London, and New York. Furthermore, the abundant blossoms of these plants are harvested by bees, a significant fact now, but even more so in earlier times when honey was the only sweetening available.

Another element of the vegetation is the dwarf palm. This is characteristic of the Mediterranean countries, especially those of northern Africa, and it has been widely introduced elsewhere.

Soils. Because of the low rainfall in these climates, leaching is slight and the soils in most cases are pedocalic. The prevailing high temperatures are conducive to weathering, and therefore the soils of the lowlands are well supplied with the products of rock decay—clay and soluble mineral salts. Humus, however, is not abundant as a rule, a condition directly attributable to the sparse native vegetation and a flora consisting of trees and shrubs rather than grass. In general, the soils have friable structure, sandy to gravelly texture, and brown or reddish-brown colors.

Topography is an important factor in soil development in areas of Mediterranean climate. These regions are characterized by steep mountain or plateau slopes descending abruptly to the sea and relatively narrow plains in the valleys and along the coasts. The topographic conditions imply eroded, stony soils on the slope lands and soils of depositional origin on the low plains. Active erosion tends to prevent the development of normal mature soils on the slope lands, and active deposition by wind or water inhibits their development on the lowlands.

The immature lowland soils are productive. They represent an accumulation of the fine particles which have been washed down from the slope lands and deposited without much loss of soluble mineral content, either along the stream valleys or as piedmont plains at the foot of the mountains. There the native vegetation flourished more abundantly than on the higher and drier slopes, and the decaying organic matter served to enrich further these immature lowland soils. Water is the great need. Where this is supplied, as in southern California or in the irrigated valleys of the Mediterranean lands, abundant harvests result (Illus. p. 160).

The soils of the slope lands, on the other hand, are generally thin and poor. This is particularly true where tillage has long been practiced. In some parts of Greece and Italy, the soils on steep slopes are protected from erosion by intricate systems of terraces. Thus, productivity has been maintained, but only through the cumulative labor of many generations of farmers. On the whole, the slope lands with their skeletal soils and their scanty vegetation are best adapted for use as grazing lands. In the most favored locations, this pasturage will support cattle; in the more rugged sections, where only coarse herbage thrives, goats are well able to maintain themselves; elsewhere, sheep raising is the most economic phase of the livestock industry.

Agriculture

The lands around the Mediterranean have, from very early times, been centers of culture, and from there our boasted modern Western civilization has sprung. Without making any claim that the early development of civilization in this area is due entirely to climatic conditions, it cannot be denied that in the Mediterranean lands substantial production has always been possible. Such production, however, has demanded both effort and thought. The future, the season of little rain, had to be considered, and thus methods of tillage to conserve moisture resulted, drought-tolerant crops were selected, irrigation systems were devised, and schemes of grain storage were planned to offset lean periods. These are impulses toward co-operation and progress, and there is little wonder that the people in such areas were stimulated to mental as well as to industrial activity, often developing a highly organized society.

Two general types of land utilization characterize the agriculture of the dry subtropical lands—the extensive, dry-land type with large farms and the intensive irrigated type with small holdings. The former includes the growing of grains, of certain drought-resistant fruits, and—to a lesser extent—grazing. Wheat and barley are the most important grains, whereas vine, fig, and olive are the major fruits. Under irrigation are raised the moisture-loving crops, with high returns per acre, especially corn, rice, vegetables, and citrus fruits. The need for production encourages full use of water available for irrigation, expansion of irrigation farming is halted by scarcity of water rather than by lack of land or markets. The needs are two-fold, namely, tap additional water supplies and use water less wastefully.

Courtesy U S Bureau of Reclamation

Irrigation farming, Yuma, Arizona Lettuce production

Grain agriculture. The winter rains and summer drought of Mediterranean climates favor early maturing crops. Small grains rather than corn are therefore characteristic of these climates. Hard winter wheat and barley are the foremost cereal crops, the former a bread grain, the latter chiefly used as a feed grain but locally important for food. They are planted after the first rains of fall or winter. The Mediterranean lands have always been noted as wheat producers, and in earlier times the attempts to insure wheat supplies were often the dominating motives in commercial and even in military contests. Control of the fertile valleys of the Nile, and of certain sections of Greece, Italy, and Spain was sought largely because of their value as wheatlands.

Durum wheat, popularly known as macaroni wheat, is the type most characteristic of the summer-dry subtropical climates. It is hardy and drought tolerant. Although its flour is not well adapted for bread making, it makes the palatable and highly nourishing tubular foodstuff known as vermicelli, spaghetti, and macaroni. The art of making these pastes is of Italian origin but has spread to nearly all lands. The Italians have taught practically the whole European world to enjoy their favorite dish, spaghetti.

Animal Industries

Since summer drought and winter rains are more conducive to bush and shrub growth than to grass, the livestock industries have centered about donkeys and mules rather than horses, and goats rather than cows. Sheep and goats are the mainstays of the pastoral pursuits. Where forage is relatively abundant and pastures are open, sheep predominate. Since sheep are timid, defenseless creatures, the herdsman's watchful care has always been essential. Out of this has come the symbolism of the shepherd in sacred story and song—a symbolism beautifully expressed in the religious rites of modern church worship throughout Christendom. The mild climate where forage is fairly plentiful but grain feeds are scarce seems to have been conducive to the development of breeds of sheep small in size but of superior quality of wool, like the renowned Spanish Merino.

Where forage is scarce, topography rugged, and the vegetation harsh and unpalatable, the sheep give way to their more active cousins, the goats. Thus, in the eastern Mediterranean lands, in northwest Africa, and in the less favored areas elsewhere, we find the goat, man's most tolerant and persistent producer. The world's major center of production of goat skins is the area reaching from Morocco and Spain in the west to Greece, Turkey, and Iran in the east. There, where neither grass nor grain is abundant, the goat exists, furnishing food for the local population and providing the finest hides to be made into gloves and shoes in the world's fashion centers.

Another phase of the animal industries that deserves attention is poultry raising. In these areas of nearly all-year growing season and low humidity, the poultry industry has a high place. The Mediterranean breeds of chickens are noted for their hustling abilities, their agility rather than size. The natural habitat, with its seed-bearing bush and flitting insect life, has been conducive to the development of quick-moving kinds of poultry. From these lands the Leghorns and Minorcas have sprung, small agile birds quite in contrast to the heavy, ponderous Asiatics. The Mediterranean breeds mature early and make high scores in egg laying. These qualities have placed them in favor as food producers and are important factors in accounting for the factory-type poultry farms of California.

Horticulture

On a large-scale basis, the dry subtropical lands are the world's principal areas for the production of olives, figs, grapes, prunes, and citrus fruits. Olives, figs, and vines are typical dry-land fruit crops of many Mediterranean areas, while citrus fruits are typical of the irrigated sections. From a world point of view, the lands around the Mediterranean Sea rank foremost in the production of olives, figs, currants, wine grapes, oranges, and almonds, while California holds first place in prunes, raisin grapes, and lemons. Grapes and citrus fruits are of economic importance in each of the other dry subtropical regions as well—South Africa, central Chile, and southern Australia.

Olives. The olive appears to have been native to Asia Minor, being one of the trees earliest cultivated by man. The gift of the fruit was a token of peace among the barbarians of early times, and a branch of the tree became a symbol of peace. The importance of the olive as a source of fat in the diet of the people of eastern Mediterranean lands is attested by the frequent references to it in sacred literature.

The olive industry is chiefly dependent upon one species of tree, the *Olea europea* or European olive, of which there are many different varieties. The tree, a tough, narrow-leaved evergreen, is noted for ease of propagation, hardihood, heavy yield of fruit, and longevity. It does not need irrigation, and therefore in the Mediterranean region olive groves are generally found on the hillsides or in stony parts of the plains. In many districts olive trees are interplanted with grape vines, or even with wheat. By the eighth year an olive grove should be in profitable production, furnishing 20 to 40 gallons of olives per tree, and should continue so for many years. The oil content varies between 15 and 30 per cent. Olive trees more than a century old are common in the Old World, and many instances are known where the age is supposed to be 500 years or more.

The olive harvest comes at the beginning of the winter rains, in the Northern Hemisphere usually in November. High-quality olives are picked by hand and kept scrupulously clean. (Illus. p. 167.) In many of the older producing sections such care is not practiced—the fruit is shaken from the trees by beating the branches with poles, and the olives are picked from the ground in more or less bruised condition. This practice lowers the quality of the oil and causes undesirable flavors to develop.

While many olives are sold for table use, most are produced for oil. Olive oil is expressed from the fleshy part of the ripe fruit; the yield of oil from a well-grown mature tree 15 years old should be from 200 to 250 pounds a year. The quality of the oil depends more upon the care with which the fruit is handled than upon the soil or climatic conditions under which the olives are produced.

Olive oil is widely used in countries where animal fats are scarce. Where climatic conditions are unfavorable for the production of feed grains and grass, large-scale production of cattle and hogs is impossible. Where butter and lard are scarce, olive oil serves similar needs. Furthermore, summer heat and dryness tend to irritate the skin, creating a need for oily ointments such as olive oil.

It is not surprising that the olive is so important in the Mediterranean lands. There the areas of winter-dry subtropical climate are most extensive, people most numerous, and demand greatest. Spain, Italy, and Portugal together produce nearly 80 per cent of the world's commercial olive crop; other important producers are Tunis, Greece, Algeria, Morocco, and Syria. California is the only important center of olive production in the Western Hemisphere. The quality of the output there is of the best, but the quantity is less than half of 1 per cent of the world's total. Although California has much land well adapted to olive growth, profits are not normally high enough even to justify thorough picking, much less expansion. During World War II the price of olives quadrupled when imports from Europe were cut off, and the California growers picked large crops.

Dried fruits. Sun-drying as a means of preserving fruit has been practiced for countless ages. Nature does this in the ripening process of grains and other seeds, and man early learned to imitate nature in the case of a number of fruits and vegetables. Until canning and refrigeration were devised, drying was the prevalent method of preserving fruits. The countries of Mediterranean climate have the advantage of their varieties of fruits with high sugar content and their dry, cloudless summers favoring sun-drying. The principal fruits preserved in this way were figs, prunes, "currants," and raisin grapes; and in spite of the tremendous development of canning and refrigeration, these still remain in high favor and are produced in quantities of great commercial importance.

TABLE III

ESTIMATED PRODUCTION (COMMERCIAL ONLY) OF DRIED FIGS IN CERTAIN PRODUCING COUNTRIES

Countries	*In Short Tons (2,000 lbs.)*			
	1935-1939 Av.	1944	1945*	1946
Algeria.......	18,500	20,900	10,300	19,200
Greece.......	22,800	13,200	19,800	21,400
Italy	87,200	70,400	59,200	60,500
Portugal.....	5,700	8,800	5,500	11,000
Turkey....	37,000	35,200	28,600	33,000

* Preliminary figures.

Source: *Agricultural Statistics, 1947*, United States Department of Agriculture, Washington, D. C., 1948.

FIGS. The fig tree appears to be indigenous to Asia Minor and Syria, and various species are found growing wild in most of the Mediterranean countries. As it is frequently referred to in Hebrew scriptures, the fig was probably one of the earliest cultivated fruits of the eastern Mediterranean lands. (See table, above.)

The fig, *Ficus carica*, is a medium sized tree reaching heights of 18 to 20 feet, with rough branches, palmately lobed leaves, and compound fruits. While it is widely grown in the tropics and subtropics, the principal centers of commercial production are in the Mediterranean countries and southern California, especially in the hotter, drier parts of these areas.

Although there are numerous varieties, the Smyrna fig is of outstanding commercial importance because of its flavor and size. It depends on fertilization by the fig wasp (*Blastophaga grossorum*), an insect that spends part of its life cycle in the fruit of a wild variety. When Smyrna figs were first introduced into California, the trees grew successfully and blossomed but failed to bear fruit. Only after the role of the fig wasp had been studied in Asia Minor, and the wild fig and wasps had been obtained, did fig culture become a success.

Fresh figs are a favorite fruit in the producing districts, but since they are highly perishable, the trade deals chiefly in preserved or dried figs. Turkey probably leads in total production. Figs are grown extensively along the coast of Asia Minor, the chief shipping port being Smyrna, whence the commercial name for the variety is derived. All the other Mediterranean countries are important producers, and most of them are also important exporters, particularly Italy, Greece, and Algeria. In the United States, California produces 99 per cent of the figs. Texas, with a small production, has the distinction of being one of the few centers of commercial fig production outside the summer-dry subtropical regions.

Most figs imported into the United States come from Turkey and Greece. With increasing domestic production the trend is toward a declining import trade. At present, domestic prices are sustained by means of import duties, a practice that does not encourage increased consumption.

PRUNES. While plums occur in many countries and climes, only a few varieties are so firm and sweet as to cure instead of spoil under natural drying conditions. The term *prunes* technically refers to plums that have been dried without removal of the seed; popularly, however, the term covers also the fresh fruit in the districts where the general practice of drying into prunes prevails. Prunes grow best along the cool and moist margins of the Mediterranean climates. In Europe, Yugoslavia is the most important producer. Although a large percentage of the fruit is used in the manufacture of brandy and jam, the exports of prunes in some years have exceeded 50,000,000 pounds, most of them going to neighboring countries.

TABLE IV

ESTIMATED PRODUCTION (COMMERCIAL ONLY) OF DRIED PRUNES IN CERTAIN PRODUCING COUNTRIES

Countries	*In Short Tons (2,000 lbs.)*			
	1935-1939	1944	1945*	1946*
United States	209,750**	163,150	233,750	221,250
Argentina	1,500	2,900	4,300	4,800
Australia	2,900	3,600	1,900	3,000
Bulgaria	9,400	2,000	3,000	3,000
Chile	1,100	1,900	1,800	2,600
France	4,700	3,800	1,100	4,100
Romania	12,000	1,100	7,700	5,000
Yugoslavia	30,500	1,100	11,000	7,200

* Preliminary figures.

** Av. 1935-1944

Source *Agricultural Statistics, 1949*, United States Department of Agriculture, Washington, D. C., 1948.

As late as 1890 the United States imported more than 60,000,000 pounds of prunes a year. Plantings in California, especially in Santa Clara county, south of San Francisco, proved so successful that California has become the world's leading prune producer (Illus. below). Prunes grow well also in the mild climates of Oregon, Washington, and parts of Idaho. Several varieties are grown, making fresh fruit available from June to November and providing dried fruit throughout the year. The United States has become the leading exporter, and prunes have gained first place in our exports of dried fruits, the quantity exceeding 200,000,000 pounds annually. Our principal markets are Canada and the countries of northwestern Europe, but American prunes are sold in nearly every market of the world.

GRAPES. All regions having the Mediter-

Courtesy Chamber of Commerce, San Jose, Calif.

Drying prunes, Santa Clara County, California ranean type of climate are noted for their grape culture. The grapes are produced for table use as well as for wine manufacture. Southern Spain has long been famous for its grapes of such high keeping qualities that they are available for table use late into the winter. Through modern methods of storage, fresh California grapes are on the market many months of the year.

TABLE V

PRODUCTION OF RAISINS AND CURRANTS IN PRINCIPAL PRODUCING COUNTRIES

Countries	*In 1,000 Quintals*			
	1934-1938 Av.	1943	1944	1945
Spain	138	107	113	77
Greece	1,948	No data	No data	600
United States	1,983	3,638	2,808	2,214
Persia	542	349	299	329
Turkey	830	698	449	649
Union of South Africa	80	113	111	112
Australia	757	1,051	701	713

Source: *International Yearbook of Agricultural Statistics*, 1941-42 to 1945-46, Bureau of the F.A.O. in Rome, Vol. 1, Rome, 1947.

RAISINS. Raisins, made by drying special varieties of grapes, are among the staple exports of most regions with summer-dry subtropical climate. The center of output of raisins, as of prunes, has shifted from southern Europe to California. Machine methods of cleaning and drying have largely, although not entirely, supplanted the older method of sun-drying. Eastern Spain, with Almeria as the centuries-old export center, still has some importance in the raisin trade. Sultana raisins, made from a variety of richly flavored seedless grapes grown in the eastern Mediterranean area, hold high place in European markets. The Sultana grapes are grown especially in Greece, on the islands of the Aegean, and in southwestern Asia Minor, where Smyrna is the export center. Greece is by far the most important country of the Old World in raisin exports. Other exporters are Turkey, Iran, Spain, and Australia. Supremacy in raisin production, though not in exports, has passed to California, where Thompson Seedless (*Sultanina*) is the leading raisin grape. The significance of this change is shown by the fact that before 1890 the United States imported 35 to 40 million pounds of raisins per year, whereas in recent years imports have been negligible, but exports range between 100 and 250 million pounds. The leading foreign markets are the United Kingdom, Canada, Sweden, France, and the Netherlands. Future development of the California raisin-grape industry is dependent on markets, because sufficient land is available to provide several times the present output.

CURRANTS. In contrast to the wide distribution of plums is the extremely limited distribution of currants, a form of seedless grape. They are grown in continental Greece and on some of the outlying islands. The name *currant* is a corruption of Corinth, the seaport long famous for exports of this dried fruit. The total annual exports of Greece are normally about 130 thousand tons. American imports of currants normally are about 6 million pounds per year, nearly all coming from Greece. Although Greece still holds undisputed first place in the world's currant industry, production is increasing in southern Australia and the Union of South Africa.

The wine-making industry. Varieties of grapes suitable for wine production, such as Muscat and Zinfandel, appear to be indigenous to southeastern Europe and southwestern Asia. Their utilization for the manufacture of wine is one of the oldest known industries, and Old Testament references give evidence of the high favor in which wine was held by ancient peoples. Because of the rather low winter rainfall and prolonged summer drought of Mediterranean countries, good water is not readily obtainable even now in many places. Wine was a thirst-satisfying drink that did not convey disease and could readily be stored for use when needed.

From an American point of view, the amount of wine produced by the leading Mediterranean countries appears enormous. The output has mounted to over 5½ billion gallons annually, France alone accounting for 1 to 2 billion gallons per year. Italy 2 is the next important producer, and other countries of high rank are Spain, Algiers, and Portugal. Although approximately 75 to 80 per cent of the wine is consumed in the countries where produced, it is nevertheless a leading export. In Spain, and especially in Portugal, the wine exports are among the important sources of national income. Northwest Europe and Canada are the principal markets, but Mediterranean wines are shipped to nearly all parts of the world.

The other regions of summer-dry subtropical climates—California, Central Chile, South Africa, and Southern Australia—have wine industries, but none has approached the wine industries of the Mediterranean countries in economic importance. This may be owing in part to the fact that wine-making depends on skill, and that it takes time to develop this skill in the newer centers. Reputation is another major factor; the high reputation acquired by the Mediterranean countries through centuries of wine-making now serves as an economic asset of tremendous value. Other regions will find this a difficult hurdle to overcome in open competition. The tendency to imitate European wines and claim equivalence for what are dissimilar products has been of doubtful benefit to certain of the non-Mediterranean wine regions.

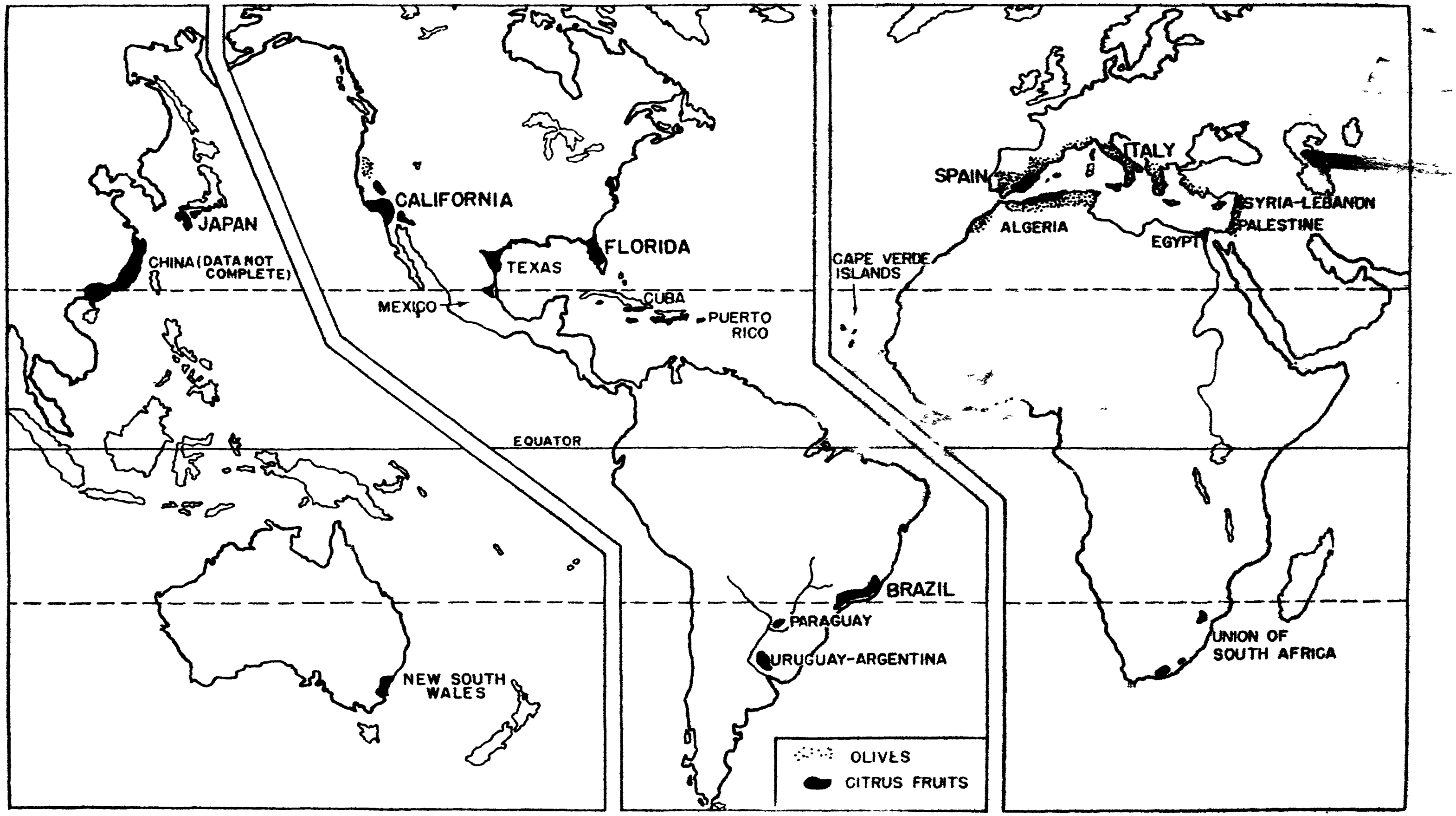
The Citrus Fruits

The orange, lemon, lime, and grapefruit, together with several other citrus fruits less widely known, are important commercial products of the subtropical lands. In a way they may be said to be commercially the advance guard of the tropical fruits to enter cool-climate markets. The two qualities which are most effective in promoting trade in citrus fruits are, first, their acid flavor combined with pleasant taste and health-promoting qualities and, second, their thick, oily, and bitter skins, which serve to protect them from insects and from bruises in shipment. The warm subtropical to tropical lands of southeastern Asia—China and Indo-China—are the ancestral homes of the citrus fruits. From southern Asia, sweet oranges were introduced into the Mediterranean countries by the Portuguese in the latter part of the fifteenth century, and thus a beginning was made of an important and enduring industry. From Spain, the citrus fruits were carried to the New World, and they now are cultivated in nearly all the tropical and subtropical lands of the world (Illus. p. 167).

Citrus fruits are produced most successfully under conditions of high temperatures and sunny days. The summer-dry subtropical regions lack a sufficiency of rainfall during the warm season, but where water can be supplied by irrigation, conditions are optimum for growth. Inasmuch as oranges and lemons are of leading commercial significance in regions of Mediterranean climate, they will be discussed here, although areas of important promotion lie in regions of humid subtropical climate. Conversely, grapefruit will be discussed in Chapter Twenty, as the major area of production lies in the humid subtropics.

Lemons. The lemon was the first of the citrus fruits to be introduced into Europe. The healthful qualities of lemons have long been recognized. The British Merchants Shipping Act of 1867, still in force, specified that every British ship destined for countries where lemon or lime juice cannot be obtained must provide a sufficient supply to give one ounce of such juice daily to each member of the crew. This measure was intended to prevent scurvy; its effectiveness is now known to be due to the high vitamin content of citrus fruits.

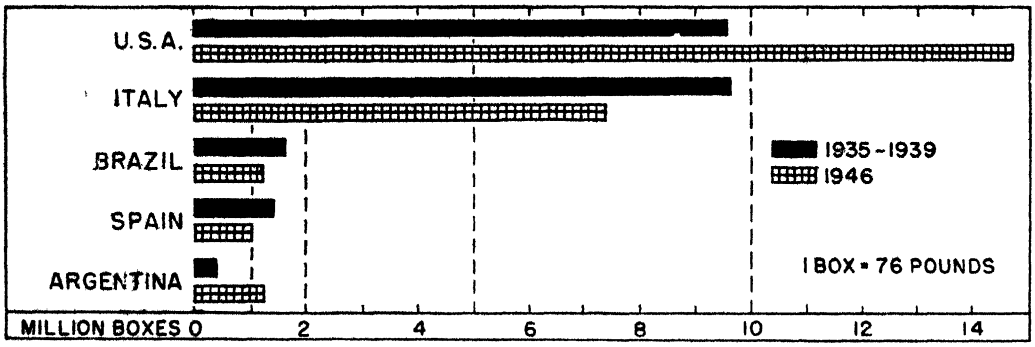
The lemon tree does not grow tall; it rarely reaches a height of more than 10 to 12 feet. A mild climate with much sunshine and without freezing temperatures,



Principal centers of production of citrus fruits and olives.

with fertile soil and an ample water supply, are the essentials for successful lemon production. In southern California 12 inches of irrigation water per year are needed to supplement the natural rainfall. The crop is picked during winter and spring and stored to meet the heavy summer demands.

The two most-feared dangers are fungus diseases and frost. A fungus disease has caused serious losses to the lemon growers of Italy. To prevent this fate, the growers in California take great care to insure ample light and air to all parts of the tree. Pruning is scientifically done, trees are spaced so as to avoid overcrowding, and spraying is carried on methodically to destroy insects and to limit fungi. When danger of freezing is imminent, oil-burning heaters are placed throughout the groves, and if possible a liberal supply of water is run into ditches and laterals. These operations involve care and cost, but results have justified them.



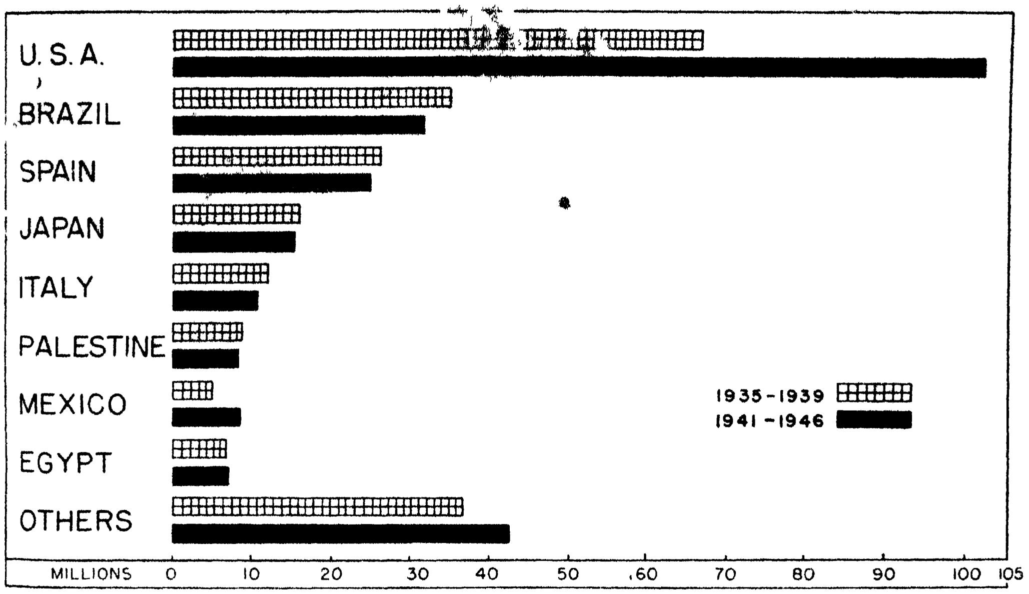
Production of lemons by 5 leading countries, 1935-1939 and 1946.

The increasing competition with other citrus fruits has produced a stationary situation in the lemon industry. The lemon groves of Italy and Spain are nearly all in bearing and there is a declining tendency in production. In California, however, a large proportion of the trees have not yet attained full maturity, and therefore production is on the increase. The United States (California) is now the world's principal lemon producer, with a harvest of 11 to 17 million boxes (79 pounds each) annually. Our imports, which averaged 2½ million boxes annually from 1909 to 1913, have been negligible since 1937. Italy, long the unchallenged leader, now stands second, with an annual production of about 10 million boxes in normal years. Brazil, with an annual production of about 1½ million boxes, forged ahead of Spain for third place about 10 years ago. Many other countries with subtropical areas produce lemons, but of these only Argentina, Chile, and Palestine have shown notable increases in production during the past decade (Illus. below).

Oranges. The orange is widely grown in tropical and subtropical lands the world over. In some places, such as parts of Paraguay and Brazil, the natural conditions are so friendly that the tree grows wild. Although production on a noncommercial scale is widely distributed in some of the warm humid lands, especially in Japan and southern China, commercial production centers largely within the regions of summer-dry subtropical climates, each of which has an important orange industry. Important centers of commercial production have, however, developed in some areas of more humid climate, such as Florida and Brazil (Illus. p. 169).

The growing of oranges has long been important in the Mediterranean countries because of the warm temperatures that favor such a frost-sensitive crop. Large export markets are provided by the millions of people of northern and western Europe who are readily reached by numerous railroad and steamship lines.

Oranges are of many varieties but fall into two principal classes: the sweet and the bitter. The former is by far the more important and is the kind generally referred to. The bitter orange is grown to some extent in Spain, chiefly for its rind, which is used in the manufacture of English marmalade and of *curaçao,* a liqueur that has long had world fame as a unique product of the Netherlands. There are many kinds of sweet oranges, but their ripening periods are such as to divide them into two main groups: winter and summer oranges.



Orange production by leading countries. Quantities are expressed in boxes of 70 lbs. net weight each.

ORANGE PRODUCTION: MEDITERRANEAN COUNTRIES. Spain leads all countries in exports of oranges and is third in production, surpassed only by the United States and Brazil. The producing districts lie mainly along the Mediterranean coast, the province of Valencia being the leading center. Most of the Spanish oranges move by water to the countries of western Europe, but the rail shipments across France to central Europe are increasing. Northwest Europe is the principal market, the United Kingdom and Germany normally taking about 60 per cent of the total exports, while France, Belgium, the Netherlands, and the Scandinavian countries take lesser amounts. Shipments of Spanish oranges begin in November and continue heavy until May or June, after which the movement is negligible.

The total production of oranges in Spain ranges from 20 to 35 million boxes (70 pounds equivalent) per year. Present indications are that Spain will be able to maintain its leading position as an orange-exporting country, furnishing usually well over half of the total entering international trade.

Italy ranks about fifth or sixth in production but is an important exporter; of the total crop of 8 to 13 million boxes, 35 to 40 per cent are exported. Lack of standard methods of grading and boxing formerly handicapped the sale of Italian oranges in foreign markets, but great improvement in these particulars has been made in late years. Italy's location is advantageous in respect to the markets of central and eastern Europe. Production seems to be about stationary, no marked changes in output having been reported in recent years.

Palestine has lately become a major producer of oranges, with an annual crop of 5 to 10 million boxes. Exports have increased to such an extent that recently Palestine was the second major exporting country, following immediately after Spain. In 1939 exports reached the record figure of 12,500,000 boxes.

Less important producers of oranges are Algeria, Syria, Egypt, Greece, Tunisia, Turkey, and Cyprus. As a whole, the Mediterranean region promises to hold its place as a major citrus fruit producing area, favored as it is by soil and climate and by ready accessibility to the world's greatest markets.

South Africa and Australia. Although the quantities are small when compared with the Mediterranean region, oranges have been produced on a commercial scale in the Union of South Africa and in Australia for a number of years. Especially in South Africa expansion has been rapid, production increasing from an average of 2,280,000 boxes during 1930-1934 to 6,860,000 in 1943, but decreasing to 4,000,000 in 1946. The British Isles provide the most important market for the Union, while most of the Australian exports go to New Zealand.

South America. Except in Brazil, the production of oranges in South America is chiefly for home consumption. Brazil, now in second place, shows a definite trend toward substantial increase in both production and exports, a movement encouraged as a national policy in order to lessen the dominance long held by coffee. Brazil's production during the years 1941 to 1946 was estimated at from 27,000 to 36,000 boxes. Brazil produces the navel—a seedless so-called winter orange also important in California—and markets it during our summer. Thus the Valencias of Spain and the United States are beginning to meet heavy competition from the navels of Brazil in the great import centers of the Northern Hemisphere.

Japan and China. China, the probable home of the orange, is an important producer, but complete data as to quantities are not obtainable. Most of the oranges are consumed locally and do not enter the channels of foreign trade.

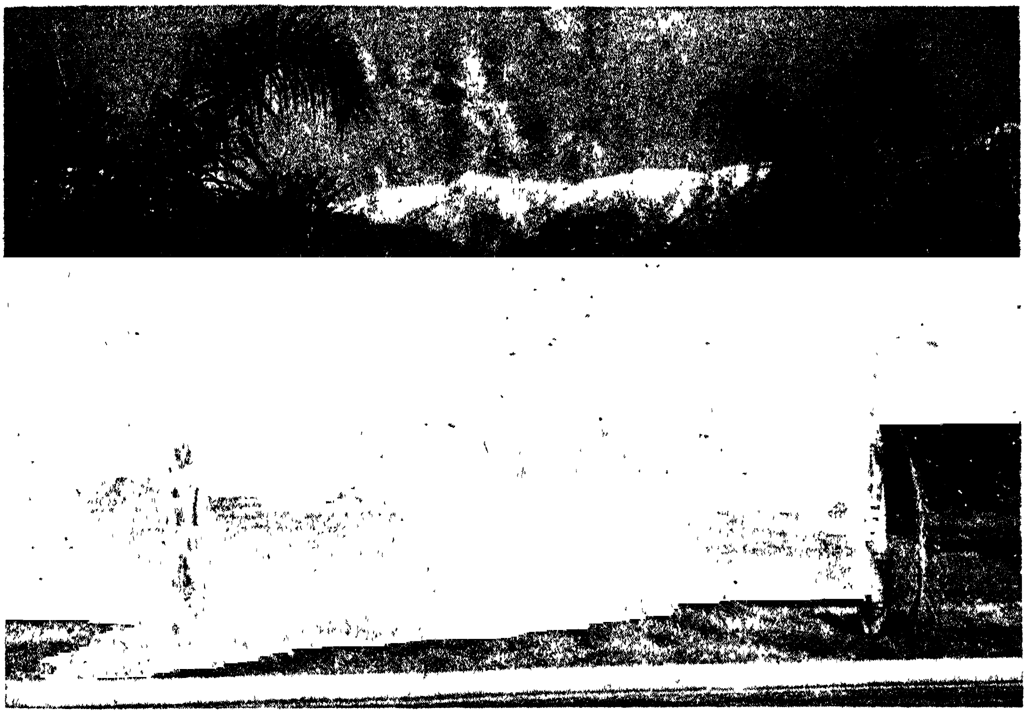
In orange production Japan ranks fourth among the countries. Before World War II the crop averaged about 16,000,000 boxes. About 75 per cent of the Japanese oranges are tangerines, known also as *mandarins*. The chief markets include Korea, Manchuria, and the near-by provinces of China, although normally considerable quantities are shipped to Canada and the United States.

Of course, neither Japan nor China has the Mediterranean type of climate. Oranges are grown without irrigation in the humid subtropical areas in the southern parts of those countries.

The United States. The United States has become the world's largest orange-producing country, and the trend here, as in most other orange producing centers, is definitely upward, with annual output of over 117 million boxes having been reached in 1946. California and Florida are the two principal areas, both large and capable of greatly increased output; lesser quantities are produced in Texas, Arizona, and Louisiana. Wherever oranges are grown, subtropical temperatures are found, but the rainfall varies from humid Florida and Louisiana to summer-dry California.

Florida was the earliest region of large production. After the Civil War, northern Florida found orange production highly profitable, and therefore extensive plantings were made. Several setbacks by cold waves caused moderate losses, then came the disastrous freezes of the winter of 1894-1895, during which even the trees were killed. These disasters led to a shift in the commercial orange culture to the southern half of the state, where losses by freezing were less likely to occur. Since 1920 great expansion has taken place, and Florida has reached a high place in the winter Valencia juice-orange trade.

The orange groves of California are subject to greater winter cold than are those of Florida, but the damage is not so great because the temperatures are more stable and are not interspersed with warm spells that bring the trees into active growth. For protection against frost, nearly all orchards are equipped with oil-burning heaters which can raise the air temperature several degrees. Irrigation is of course necessary during the dry summers. Extensive and highly efficient irrigation systems have been developed. The mountains rising back of the coast have furnished the necessary catchment areas, but even so the local water supply is not sufficient to furnish irrigation water for all the available land (Illus. above).



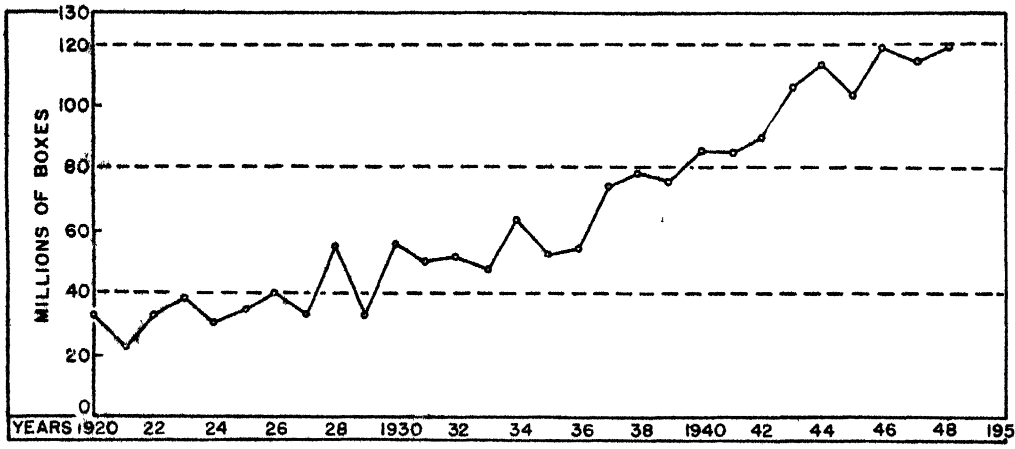
Courtesy Chamber of Commerce, Los Angeles

Orange groves, Los Angeles County.

California has long been noted for its production of navel oranges for the winter markets. Economic success was achieved because of the favor with which these large, richly colored, seedless oranges were received in the markets. During the past decade or two, however, the California navels encountered increasingly keen competition from the seed-containing but juicy and well-flavored Florida product. Lower prices ruled, and as a result growers began to favor the Valencia oranges. At present, Valencia oranges constitute about three-fifths of the total California crop. The increasing demand for orange juice and orangeade has been an important factor in bringing about this new trend. However, California navels still bring higher prices in eastern markets than do Florida oranges, though in some years the greater cost of shipping across the continent nullifies the advantage to the growers of the higher price.

A third, though smaller, center of orange culture is developing along the Gulf Coast of Texas. Planting is actively going on, and production increased from an average of 2,539,000 boxes during 1935 to 1944 to 4,800,000 in 1945. But Texas, like Florida, must take into account the danger of freezing when the unwelcome northers sweep down to the Gulf from the cold interior.

There is a striking upward trend in orange-growing in the United States. Average annual production increased from 21,400,000 boxes in 1915-1919, to 67,300,000 boxes in 1935-1939, a jump of over 200 per cent in two decades. The total crop of 1941 reached the figure of 85,163,000 boxes of 70 pounds each and in 1946 was estimated at 118,680,000 boxes (Illus. above).



Orange production, including tangerines, U.S.A., since 1920. Boxes of 70 lbs. each.

The market for American oranges is primarily domestic, and until recent years the United States exports were confined largely to the Canadian market. The larger crops of later years have led to shipment of sizable quantities to Europe, notably to the United Kingdom. These shipments have been mostly Valencias for the summer market, since the navels encounter insurmountable competition with the large supply of low-priced oranges from Spain, Italy, and Palestine. The American export trade in oranges is encountering increasing competition from the expanding output of the Mediterranean countries in winter and of South Africa and Brazil in summer.

Viewed as a whole, the role of the orange industry in the countries with summer-dry subtropical climates is impressive, thanks to irrigation and marketing methods. The per capita annual consumption in the United States increased from less than 7 pounds in 1900 to more than 60 pounds in the late 1940's. This figure indicates the high favor in which oranges are held. Fortunately, an ample supply to meet future demands is assured by the increasing output of the producing regions of the world.

Early fruits and vegetables. The Mediterranean climates are centers of production of early fruits and vegetables for northern markets. There is an increasing shipment of so-called "primeurs," early potatoes, vegetables, and fruits from northern Africa, Spain, southern France, and Italy to the areas of dense population in northwestern Europe. In the United States, the shipments of melons and head lettuce from southern California to the northern and eastern markets call for trainloads of freight sent across country at express speed. Central Chile is profiting by a growing trade in fresh fruits and melons which can be sold in the northern markets in winter when local produce is unobtainable. Early markets are always relatively high-priced markets. Thus, the ability to provide out-of-season produce is of distinct advantage to the centers of production, and it adds materially to the standards of living in the areas served The mutual advantage of trade to both seller and buyer is well illustrated in this traffic.

Conclusion. Earlier in this chapter we mentioned the fact that through the handicap of the dry summer, and the necessity to develop irrigation, the Mediterranean climate has been conducive to the early development of more highly organized forms of society in the lands surrounding the Mediterranean sea. Here were the centers of the Hebrew, Egyptian, Greek, and Roman civilizations. In the modern world, regions of this type of climate include progressive centers in Australia, South Africa, central Chile, and California. These regions present a diversity of activities and products not excelled anywhere. Their winters, with mild temperatures and invigorating sunshine, attract visitors and settlers by the thousands. Their surpluses of fruits and vegetables are important additions to the world's food supply. All in all, the world of today owes much, in heritage from the past and in production of the present, to the lands with this type of climate.

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Chapter Eleven

REGIONS OF HUMID SUBTROPICAL CLIMATE

The humid subtropical climate of the eastern sides of the continents contrasts distinctly with the even temperatures and dry summers of the Mediterranean climate of the west coasts. The eastern climate has greater seasonal changes in temperature, and there is rainfall at all seasons except in China where winters are relatively dry.

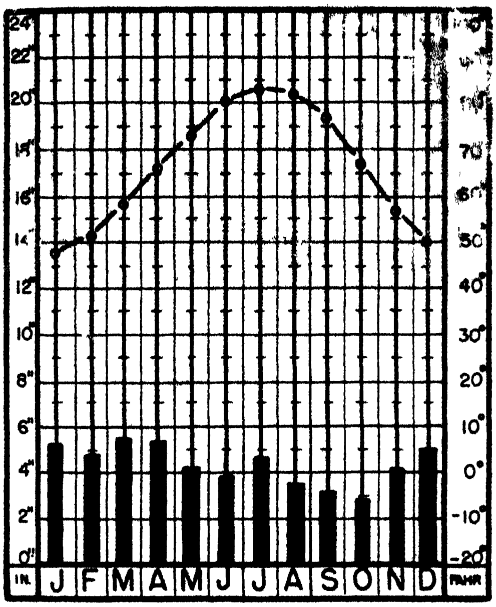
Character and Distribution of Humid Subtropical Climate

The humid subtropical climate, most important in the southeastern United States and southern China, prevails in the eastern parts of all land masses of continental size between the latitudes of approximately 25 to 35 degrees from the equator (20° to 30° in China). (See Map of World Climatic Regions.) It sometimes is called the cotton-belt climate because of the importance of cotton production in some of the regions. This type is transitional between the tropical climates toward the equator and the intermediate climates poleward; unlike the Mediterranean climate, it lacks a unique, distinctive character of its own.

Temperature. The humid subtropical regions have growing seasons of ten to eleven months, but there is the possibility of frost occurrence during one to four months each year. At the equatorward margins, there is a probability of frost only during the coldest month, whereas along the cooler margins frosts are expected during the three or four coldest months. The average temperature of the coldest month, however, is above 43°F. (6°C.), so that in many places there is but relatively brief interruption of growth of the hardier types of vegetation.

Summers are warm but do not register the extremely high temperatures reported from the interiors of the continents farther poleward. For example, in midsummer a trip from Kansas City to New Orleans is likely to carry one from scorching heat to just warm summer weather. In southern Mississippi, Alabama, and Georgia practically all summer days show thermometer readings well below the maxima reached on the plains of Nebraska and Kansas. Nevertheless, the summers in the Cotton Belt are more enervating because the nights are warmer, the humidity is higher, and summer is much longer than farther north. The "sensible" temperatures, that is, temperatures as they are felt by the human body rather than read off the thermometer, are relatively high. (Illus. p. 175.)

The winters are mild, and much vegetation remains green throughout the coldest months. Snowfall is rare in the warmer latitudes and occurs only during the severest weather in the cooler areas. In the United States the most distressing features of winter are the cold waves which occur when masses of cold continental air from the interior penetrate all the way to the Gulf Coast and eastward to the Atlantic, causing severe damage to crops and physical discomfort to man. In China, also, winter temperatures are rather severe in the lowland areas along the Yangtze exposed to the sweep of cold winds from the interior, whereas regions which are near the coast or are protected by mountain ranges have mild winters.



Humid sub-tropical climate. Average temperature and precipitation, Vicksburg, Mississippi. Altitude 247 feet, total precipitation 52 inches.

In the humid subtropical regions of the Southern Hemisphere, temperature changes during the winter are much less pronounced than in like regions in the Northern Hemisphere. This is due to the predominance of marine influence—result of the lack of land masses poleward. Winters are milder and temperatures are less variable.

Winds. The winds are generally light and variable. In the summer, warm tropical winds predominate. This is particularly true in China and the United States because of the monsoonal conditions brought about by the large land masses of Eurasia and North America. As winter approaches, the belt of cyclonic storms reaches these regions, becoming dominant in the cooler portion, but only partially so in the warmer. In the United States, the cyclonic storms, with occasional cold waves, are encountered more and more intensely and frequently as one goes northward in this area from Florida to Virginia. In China, the in-blowing monsoon dominates the summer and cold, out-blowing monsoon winds rule the winter. The climate of southern China therefore exhibits greater seasonal differences than do other humid subtropical areas. The winters are drier and considerably colder than one would expect judging by latitude, whereas in the other regions the winters are short, mild, and rainy.

During the latter part of summer, tropical hurricanes occasionally reach the coasts, causing serious damage to crops and shipping. Although usually less vigorous than in tropical latitudes, they constitute a menace to orcharding and city building that must be reckoned with along the Gulf and South Atlantic coasts of the United States and in southern China and Tonkin. Since these late summer storms are most likely to occur when crops are approaching the harvesting stage, they often cause severe losses. Damages to orchard crops may be especially serious, because often the trees as well as the fruit are destroyed.

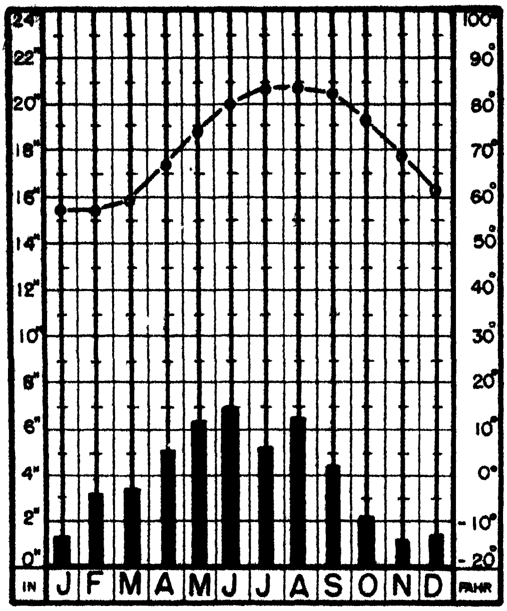
Rainfall. The rainfall is heavy, the annual average ranging from about 35 to over 60 inches. On the whole, the average in regions of humid subtropical climates is more than double that of the Mediterranean regions. Furthermore, except in China, the rainfall is more evenly distributed throughout the year. In the southeastern United States there is no prolonged dry period (Illus. p. 175), but since the autumn usually receives less rain than do the other seasons it is often called dry. Most of the precipitation occurs as rain, although some snow falls every winter in the northern sections. Along the southern margin snow is rare, in some places unknown.

The high relative humidity which prevails in winter causes even the mild temperatures of that season sometimes to feel raw and disagreeably cold. Since the houses, as a rule, are not built to withstand cold and are not provided with heating systems, during the winter season poorly clad people shiver and shake and hope for spring.

Climatic conditions in the other humid subtropical regions of the world bear a general resemblance to those in southeastern United States, but they differ in some phases. Southern China, for example, has much more distinctly seasonal variation in rainfall (Illus. right). The southerly winds of the summer monsoon give rise to high temperatures and much rainfall; the northerly winds of the winter monsoon are cold and dry.

The humid subtropical region of South America extends northward to the truly tropical conditions in Brazil and Paraguay and southwestward to the semiarid plains which lie at the foot of the Andes. Within this extensive region, the rainfall conditions vary widely. Precipitation is well distributed and generally quite dependable in the heart of the River Plate area, but toward the margins of the region, especially on the westward front, it is lower and less dependable. Severe droughts, which often result in heavy losses in grain and forage crops, are not infrequent there.

Native vegetation. Under prevailing conditions of abundant rainfall and moderate temperatures, forests are the predominant native vegetation, as they are in humid lands bordering to the north and south. The humid subtropical lands lack a distinctive vegetation type of their own. Savannas, or grassy plains, are usually limited to areas such as occur in some of the low-lying islands and on the tidal flats of the Carolinas, where the ground is so water-soaked that trees will not thrive. The Argentine Pampa is, however, a conspicuous exception to this prevalence of forest. The original vegetation of the Pampa was a treeless grass steppe, consisting in the more humid sections of a closed grass cover, but in many areas of tall bunch grasses. The former constitute the so-called *pasto tierno* (soft grasses), the latter the *pasto duro* (hard grasses). This prevalence of grass vegetation was probably due only partly to climatic causes, and largely to the fact that much of the Pampa is underlain by eolian loess deposits, or alluvial redeposited loess. At present little remains of the original vegetation. Much of the land is in crops, and trees have been planted in and around the settlements.



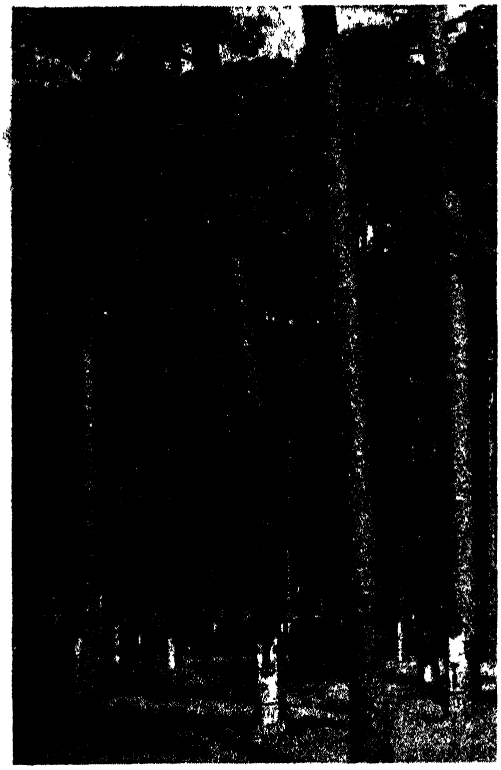
Humid sub-tropical climate (monsoon variant). Average temperature and precipitation for Amoy, southern China. Altitude 12 feet, total precipitation 47 inches.

Three broad groups of trees are dominant: the broad-leaved evergreen, the broad-leaved deciduous, and the narrow-leaved evergreen. The first group is an extension of a type common in the tropical rain forests. The other two groups, much the most common in this climate, are extensions from the intermediate climates farther poleward. Where winters are mildest, the broad-leaved evergreens are most numerous, magnolia (Illus. below) and live oak being among the best known. Thus, along the warm margins of these climatic areas, as in Florida and along the humid Gulf Coast of southeastern United States, in southern China, in northern Uruguay, and in southern Brazil, the broad-leaved evergreen trees predominate on the better soils.

Along the poleward margins the winters are sufficiently severe to induce seasonal leaf fall. In these areas the broad-leaved deciduous forest is dominant on the richer lands, oaks and poplars being the most common representatives. Narrow-leaved coniferous forest is found on the higher lands with thin soils and on lowlands with poor, sandy soils. Thus, extensive pine forests characterize the sandier portions of the Cotton Belt of the United States (Illus. right) and the *Araucaria*, another conifer, flourishes on the hilly lands of parts of southern Brazil. Southeastern United States was for years the principal source of supply for yellow pine lumber for domestic markets. The industry, however, has carried on logging operations so ruthlessly, without any attempt at reforestation, that the timber supply of the South now is seriously depleted. In general, the cut-over pine lands are not agriculturally productive; large areas are suitable only for forest and should be so utilized. The tung industry of the Gulf states is one of the few adapted to utilization of the cut-over lands. The lands where broad-leaved vegetation abounds are the ones best adapted for agriculture.

Courtesy U S Forest Service.

Evergreen magnolia tree near Gulfport, Mississippi. Exceptionally large, has 80-foot spread



Courtesy U. S. Forest Service

Long leaf yellow-pine forest in Louisiana

Soils. Inasmuch as the regions of humid subtropical climates are transitional between the seasonal warm and cold of the middle latitudes and the all-year warm of lower latitudes, and between the humid coastal areas and the drier regions of the interior, it is not surprising that the soils likewise should show transitional characteristics. The influence of the prevalently higher temperatures in the equatorward areas is reflected in the distinctly reddish soils, while in the poleward areas the soils generally have a yellowish color. In the warmest, most humid areas, lateritic soils similar to those described in Chapter Seven are not uncommon. In general, the mature soils are of the groups known as the red and yellow soils.

Because of the high rainfall, the soils are so fully leached that they are weak in lime and other soluble mineral salts and therefore belong to the general group of the pedalfers. Structurally they vary from fairly stable soils, similar to those in cooler climates, to weak soils, such as are commonly found in the tropics. Inasmuch as soils with weak or poor structure entail heavy costs in labor and fertilizers if productivity is to be maintained, wise selection of lands is necessary for successful agriculture.

The alluvial lands are in general the most productive. In southern China, agriculture is practically limited to the flood plains along the numerous streams; among these, the plains of Szechwan on the upper Yangtze River, the plains of Tungting and Poyan Lakes, and the valley and delta of the Si River are the largest and the most densely populated. In North America, the Mississippi is bordered by a notable belt of very rich alluvial soil. In Argentina, the broad plains of the Pampa have young loessal (eolian) soils of high fertility, to which much credit must be given for the successful agricultural development of that region.

In southeastern United States the upland soils are relatively poor and require continued application of large amounts of fertilizer and labor for profitable production. This is a decided handicap when the crops must be sold in competition with those of soils upon which such costs are lower. From a climatic point of view, corn can be raised successfully, and good yields are obtainable; nevertheless, corn is of slight importance as a commercial crop because farther north in the United States it yields more heavily and with less expense for fertilizer. Cotton, like corn, can be grown only with the use of heavy applications of fertilizers, but unlike corn the crop does not have to compete in the market with one raised without such expense.

Land Utilization

Agriculture. The humid subtropical regions are capable of producing a fairly wide variety of crops especially on the better soils. The growing seasons are long, the winters are short and mild, and the rainfall is sufficient. However, many areas such as the sandy regions of the American South, or the hilly land of southern China, have poor soils while in regions of medium fertility soils leach easily, and the problem of maintenance of fertility must be met.

The transitional character of the humid subtropical areas applies to their crops as well as to their natural conditions. They have few distinctive crops not shared by areas of other climates. In southern China and southeastern United States, the warm margins raise subtropical products, whereas the colder margins produce temperate cereal crops. The Pampa region has cooler summers, moderate rainfall, and excellent soils. Partly as a result of these circumstances, corn, wheat, alfalfa, and cattle raising predominate.

In southeastern United States cotton still is king, though over a shrunken realm. In central China cotton is important as a summer crop, but there and in southern China rice is the main grain crop. Although little cotton is grown in the humid subtropical regions of South Africa and Australia, it is of such great importance in America that the term *cotton belt climate* is, perhaps, justified to designate the type.

In the United States the agriculture of the humid subtropical region rests broadly upon a three-fold basis. In the extensive middle zone cotton is the dominant crop. This zone is flanked on the south by a belt in which the growing of citrus fruits, early vegetables, and berries predominates, and on the north by a belt of mixed farming: cotton, corn, oats, wheat, and tobacco. Throughout the region corn is grown for local use as food for animals and man. In the Cotton

Belt, corn dishes such as corn pone and johnny cake are much more popular than in the Corn Belt to the north.

Livestock. Although the humid subtropical climate is, in general, friendly to animals as well as to plants, it is not noteworthy for livestock production. Feed is plentiful, but the native grasses lack the high nourishing qualities which are characteristic of the grasses in cooler climates. Insects are so numerous, especially ticks, that they are a serious handicap to the development of a dairy industry. The ravages of ticks can be controlled by dipping the cattle at frequent intervals, but since the effectiveness of this method of control depends on its usage by all, organized enforcement is necessary—and that adds to the expense of production.

Since horses do not thrive well in regions where summers are long, warm, and humid, mules, which are much more tolerant of these conditions, are the most commonly used draft animals. The mule has long been the mainstay of cotton production. Working either singly or in a two-mule team, his presence was as essential to the American cotton landscape as the Negro cottage with its Judas tree. However, the general introduction of tractors, and machine methods of cultivation and harvesting now in progress, are bringing about a change to less picturesque but more efficient methods of production. Hogs abound, usually lean and fleet of foot, quite in contrast to their rotund cousins of Iowa. Poultry are kept as adjuncts to the farm because they convert into palatable foods what would otherwise be wasted. In the humid subtropical area of the United States cattle ranching is carried on extensively in areas where land values are low and grasses are fairly plentiful, and dairying has developed where market and other conditions are especially favorable. The increase in livestock raising in the southern United States in recent years, based upon maintenance of sod on steep slopes and the use of legumes in rotation, represents a marked improvement in land use. However, these livestock industries do not find it easy to compete with regions of cooler climate, more nutritious grasses, higher yielding crops, and fewer insect pests.

In China, the great density of population is not conducive to livestock raising, as it is more efficient to utilize food directly than through the intermediary of animals. However, the efficient hog is very important.

A signal exception is the Pampa region of Argentina, where the production of beef plays a leading role. For a long time cattle ranching was the only industry in this region, but as the population has increased, cattle raising has been supplemented by the production of wheat and corn for export. However, as yet, less than half of the Pampa is under cultivation, and cattle raising, in association with the production of feed crops such as alfalfa, remains a major phase of agriculture. In southeastern Australia, also, the livestock industry, especially dairying, is very important.

Cotton

Although the agricultural activities in humid subtropical regions are quite diversified, cotton is an outstanding cash crop. The world's greatest area for the commercial production of cotton lies in the regions of humid subtropical climate in southeastern United States and in the immediately adjacent portions of drier and cooler climate to the west and north. Much cotton is grown also in tropical savanna areas, as in India and Uganda. With the aid of irrigation, high-quality cotton can be grown successfully in regions with warm steppe and desert climate, as in California, Turkestan, Peru, and Egypt. (Illus. p. 180.)

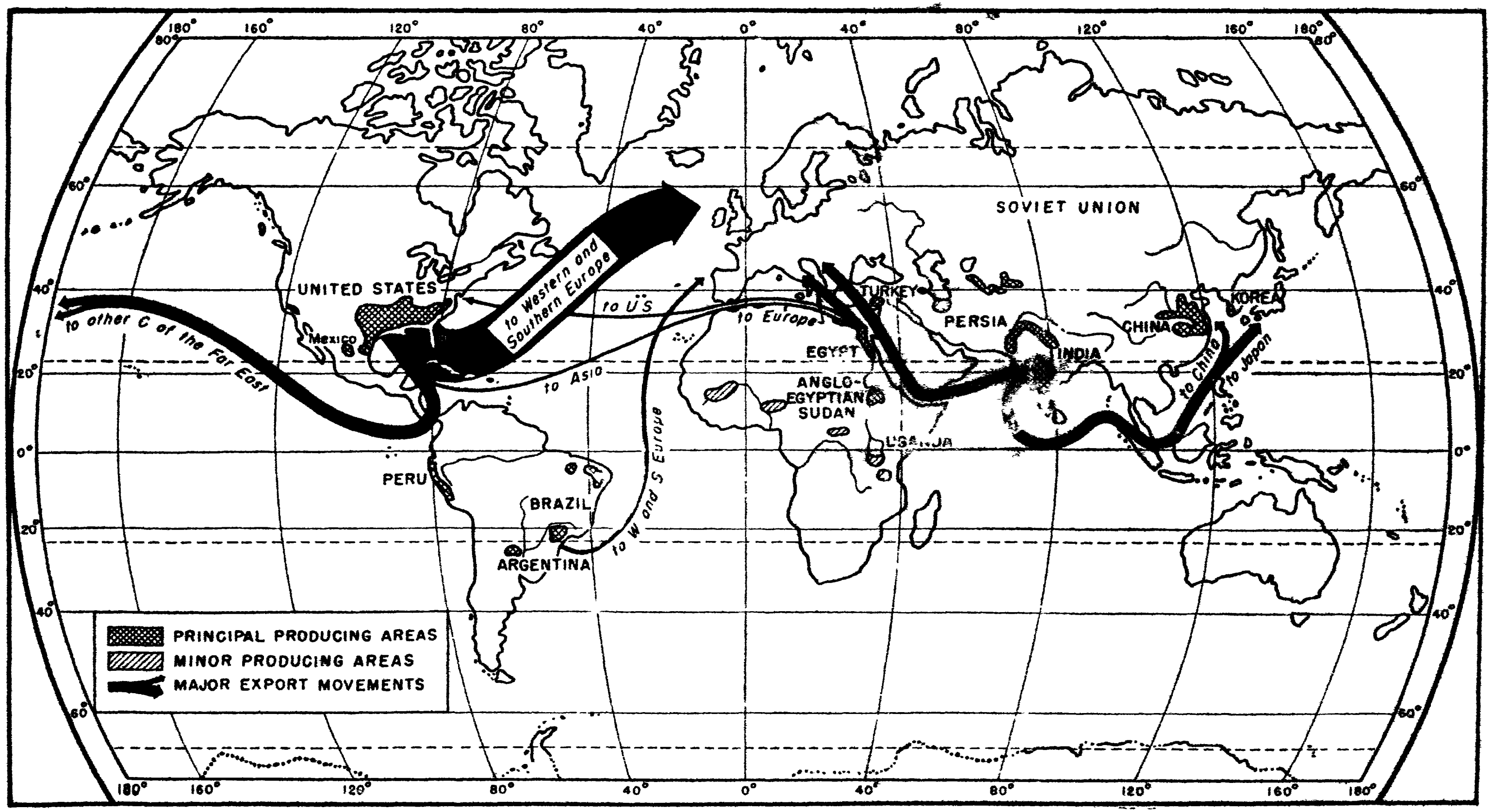
Climatic requirements. In the United States, cotton is grown only where the frostless season is more than 200 days and where the average summer temperature does not fall below 77°F. During the period of vegetative growth sunshine must be abundant, and the nights as well as the days must be warm. As a result of these rather exacting temperature requirements, the cultivation of cotton is found only from the tropics to the warmer parts of the temperate zone.

The cotton plant needs a moderate amount of moisture, well distributed throughout the growing period. An annual rainfall of 30 to 45 inches, or its equivalent in irrigation water, is considered most favorable. During the harvesting season, however, comparatively dry weather is essential, because the quality of the cotton fiber in the open boll is impaired by rain and high humidity. As the areas of rainy tropical climate generally lack a pronounced dry season, cotton cannot be cultivated successfully there. On the other hand, tropical savanna and humid subtropical climates usually have long enough dry periods in the fall to favor cotton harvesting. In Mediterranean or in arid climates, cotton can be raised only with the aid of irrigation (Illus. below).

Courtesy U S Bureau of Reclamation

Irrigating cotton in San Joaquin Valley, Calif. Efficient water usage necessitates watchful care.

Historical significance. Cotton was used for the manufacture of coarse cloth by the Indians of northern South America, Central America, and the West Indies before the arrival of white men. It was a cultivated plant in India before the dawn of history and was grown in Egypt as early as the fifth century B.C. Not until the end of the eighteenth century, however, was the cotton fiber first used by the textile industries of western Europe. At that time, most of the raw cotton came from the Near East, although small quantities were imported from the West Indies and the Guianas. The fiber had to be separated from the seeds by hand or by primitive machinery. This laborious and costly

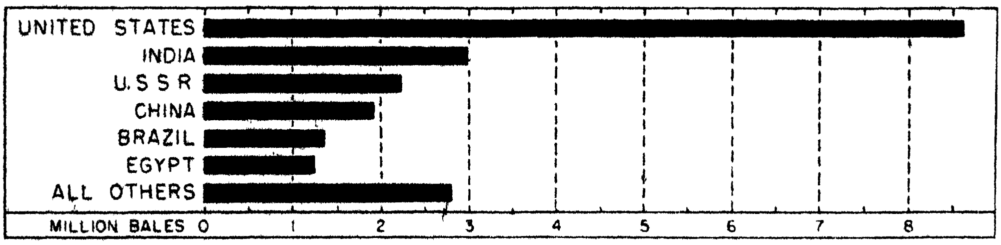


Principal cotton producing regions of the world and trade in cotton.

method made cotton too expensive for general use in cloth manufacture. The invention of the saw gin by Eli Whitney in 1793 made possible cheap mechanical separation of fiber and seed.

The spectacular growth of the cotton industry in England and in New England opened the first chapter of the Industrial Revolution. Cheap machine-made cotton cloth began to replace linens and handmade cottons in many parts of the world, thus creating an immense market. In response to the increasing demand, cotton acreage rapidly expanded, especially in the United States. In the South, cotton began its rule, which, for better or worse, has lasted until the present.

Principal cotton regions. Much harvesting of cotton still is done by hand labor. A competent picker is able to gather about 150 pounds a day. Cotton, therefore, requires not only favorable climatic conditions, but also much cheap labor, manual or mechanical. Only certain sections of the subtropical and tropical savanna regions can meet both of these requirements. Commercial cotton production at present is limited to a rather small number of well-defined regions (Illus. p. 181), among which the most important are the southern part of the United States, India, Pakistan, central China, Russian Turkestan, Brazil, and Egypt. Of secondary importance are Peru, Mexico, Uganda, the Anglo-Egyptian Sudan, Korea, and Turkey. The United States produces more cotton than all the other regions combined (Illus. above).



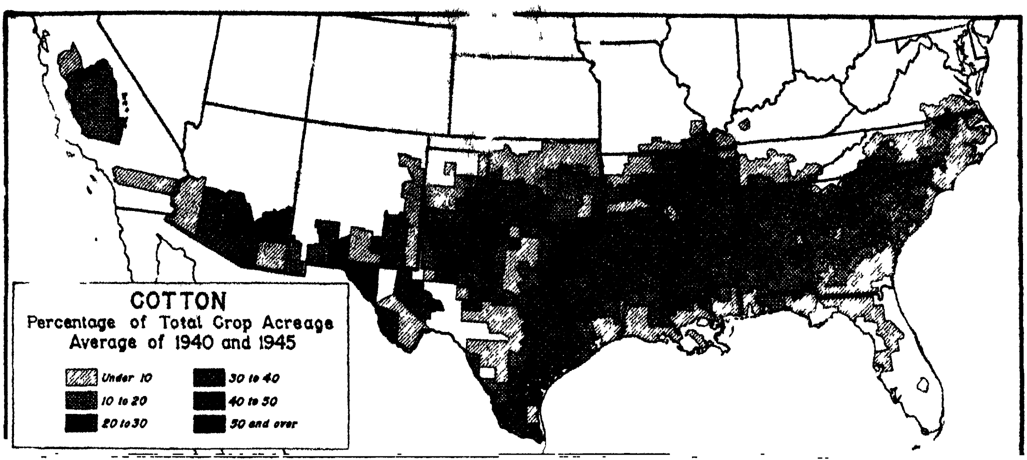
Source of data: U. S. Dept. of Agriculture.

Cotton production, principal countries. Average 1945–1946.

Types of cotton. From a commercial point of view, cotton is classified on the basis of the length of the fiber or the staple. A difference of $\frac{1}{16}$ inch in length sometimes makes a difference of $25 per bale in price. Cotton with a fiber of less than $1\frac{1}{8}$ inches is classified as short staple; of more than $1\frac{1}{8}$ inches, long staple. By far the largest part of the cotton crop of the world is short staple. Staple length determines the use to which the cotton can be put: the longer the staple, the finer and stronger the yarn that can be spun and the finer the cloth that can be woven. The finest cotton dresses use long-staple cotton. Short-staple cottons make coarse yarns and therefore coarse cloth. Some cottons have such a short staple that they are hardly fit for use in the manufacture of cotton textiles, but they, with "linters" (fuzz of cottonseed), are a source of cellulose for the manufacture of rayon.

Cotton in the United States. The United States during the decade of the 1940's has produced between 40 and 55 per cent of the world's cotton and consequently is still the dominant influence in the world market. The Cotton Belt lies south of the 36th parallel and east of the 100th meridian. Because of high rainfall and high humidity during the harvesting season, no cotton is grown in most of Florida and but little within 40 or 50 miles of the Gulf or Atlantic Coasts. Cotton is grown on various types of soil, from sands to light clays, but the yields are highest on the black prairie soils of Alabama, Mississippi, and Texas, and on the bottomlands of the "Yazoo Delta" above Vicksburg. Still higher yields are found in the irrigated cotton regions of the southwestern states. As the annual rainfall is heavy and the ground does not have the winter protection of freezing, commercial fertilizers must be applied liberally to the leached soils over all of the Cotton Belt east of Texas and Oklahoma in order to insure even moderate yields of fiber.

The area in cotton has increased steadily from less than 10,000,000 acres in 1870 to a peak of 44,608,000 acres in 1926, and cotton still is the leading crop in most of the southern states (Illus. below). Since the early thirties, however, there has been a sharp decrease in acreage, and since 1933 it has usually remained well below 30,000,000 acres and has even dropped below 20,000,000 in 1945 and 1946. These changes in total acreage have been accompanied by pronounced changes in distribution. The once solid Cotton Belt has been broken into a few large areas of cultivation: in South Carolina and southern North Carolina; in the Mississippi region of Arkansas, Louisiana, Tennessee and Mississippi; in a region on the borders of Arkansas, Louisiana, and Texas; in eastern Texas and in northwestern Texas. In the Carolinas, Georgia, and Alabama, cotton has lost ground through the years, whereas west of Alabama it has gained. Texas now is the leading producer and Mississippi is second. In most of Texas and Oklahoma yields of nonirrigated cotton are low, but the farms are larger than in the older parts of the Cotton Belt, and since all the bolls ripen at approximately the same time the cotton can be picked mechanically at low cost with little wastage (Illus. B, p. 184). The dry climate of these states has proved to be of great advantage in limiting the depredations of the boll weevil, which flourishes in the more humid environment to the east. An added advantage of the region west of Alabama is that the soils are more fertile so that less fertilizer is needed.



UNIVERSITY OF MARYLAND DEPARTMENT OF GEOGRAPHY

U.S. DEPARTMENT OF AGRICULTURE

Percentage of tilled land in cotton in the southeastern states. Cotton under irrigation is important in Arizona and California but total quantity produced is less than that of the southern states, notably Texas, Mississippi, and Arkansas.

Another factor of economic significance is that the bulk of the crop in the American Cotton Belt is essentially of one type. The upland short-staple cotton, the longest of the short-staple cottons and often referred to as "middlings," constitutes more than 90 per cent of the total. It has considerably longer fiber than the Asiatic cottons, and therefore is in great demand by cotton spinners all over the world. Production of long-staple upland with fibers of 1⅛ to 1¾ inches is limited to certain sections, especially the

Pecos and Red River Valleys of Texas, the Mississippi Delta, and lands in the southwest.

Cotton has put an indelible mark upon the entire economic and social life of the southern part of the United States. The plantation system and Negro labor were largely responsible for the rapid spread of cotton cultivation during the first half of the nineteenth century, introducing a monocultural system of agriculture with all its attendant evils. The old system of slavery has been supplanted by a system of tenancy, from 60 to 70 per cent of the farms in the cotton states being operated by tenants, while white farmers produce considerably more than half of the crop.

Courtesy Association of Commerce, New Orleans, La

(A.) Cotton bolls open ready for the harvest. Shows picking by hand. This method of harvesting is still general throughout most of the cotton regions of the world.

Courtesy International Harvester Co

(B.) Harvesting cotton with cotton picker.

Most of the cotton, especially in the old part of the Cotton Belt east of the Mississippi, is grown on small farms. The necessity of hand-chopping and hoeing and picking by hand limits the acreage of cotton per farm, and few other crops can be grown because the labor peaks nearly coincide with those for cotton (Illus. at left). The small size of the farms prevents the use of much farm machinery, although in recent years mechanization has increased in the Delta area, the Texas black Waxy area, and especially in the western semiarid sections. With it the size of the farms has tended to increase.

Until recently, mechanical picking of cotton has been handicapped by inefficient machinery; but improvements now being made point to rapid increase in the years immediately ahead (Illus. above). The problem is two-fold, namely, to maintain the grade of the picked cotton and to avoid damage to the plant while many bolls still remain unready for picking. For many years educational and agricultural leaders have been urging more diversified farming, and their efforts are at last bearing fruit. More recently the federal government has entered actively into the program of planned production, and through its influence the trend is shifting somewhat. The use of soil-building and soil-protecting crops is being encouraged. The acreage in *lespedeza* has more than doubled in the south in the last few years, and contour plowing is now a common practice. Even so, we may still expect cotton to remain the major crop in large sections of the American South.

Ordinarily, about 40 per cent of the American cotton crop has been used in domestic manufactures and 60 per cent has been exported, principally to European countries and to Japan. During the war exports dropped sharply, and even after the war the exports have remained well below the prewar figures. It remains to be seen whether foreign countries will ever again be able to absorb as much of the American cotton crop as they did formerly. The principal cotton shipping ports are Galveston and New Orleans.

Other cotton-producing countries. INDIA. Although cotton is widely grown in India and Pakistan, the principal districts lie in the western part of the Deccan Plateau (see page 181). The climate is of the tropical savanna type, with precipitation of 20 to 50 inches and a dry period which lasts approximately from October to June. In the western part of the Deccan Plateau lava sheets, comparable to those of the Columbia Plateau of the United States, have given rise to fertile black soils which are retentive of moisture and do not need irrigation. Cotton is also grown on the ferruginous soils of the southern part of the plateau. It is planted in the beginning of the wet monsoon from mid-June to mid-July and can be picked early during the dry winter monsoon, usually in November and December.

In the Punjab or Upper Indus plains, and in the Sind or Lower Indus Valley, irrigation is necessary for cotton culture. The Sukkur or Lloyd Dam, one of the largest irrigation projects in the world, provides water storage for irrigation of the Lower Indus Valley.

Although American-type cotton is grown in the irrigated districts, much of the Indian cotton has such short staple, generally less than half an inch long, that it can be used only for coarser yarns and types of cloth. Part of the crop is consumed locally or in the Bombay textile district, but more than half is exported. Japan normally is India's best customer for raw cotton, taking nearly half, but considerable amounts are also exported to China and to European countries. Bombay and Karachi are the principal ports of shipment.

TABLE VI

ESTIMATED AREAS UNDER COTTON IN CERTAIN COUNTRIES AND CONTINENTS

Areas	*In 1,000 Hectares*			
	1934-35/1938-39	1943-44	1944-45	1945-46
United States	11,193	8,762	8,097	6,977
Latin America	3,087	3,618	3,533	3,083
Asia*	13,950	10,980**	9,280**	9,090**
Africa	2,510	2,110	2,310	2,350
Soviet Union	2,027	No data	No data	No data

* Without Soviet Asia.

** Only part of China included.

Source: *International Yearbook of Agricultural Statistics*, 1941-42 to 1945-46, Bureau of the F.A.O. in Rome, Vol. I, Rome, 1917.

EGYPT. Egypt has a desert climate, and agriculture depends entirely upon the water provided by the Nile River. Cotton, famous for its long, silky fiber, occupies about one-third of the cultivated land and is grown principally on the low, fertile, easily irrigated lands of the Nile Delta. It is in great demand in Europe and the United States by manufacturers of fine yarns, fine textiles, and automobile tires. For the latter purpose, however, long-staple cotton is being replaced more and more by rayon fiber. A somewhat shorter staple cotton is grown in the upper delta and in the valley. As a whole, the production of long-staple varieties seems to be decreasing in Egypt.

CHINA. The principal centers of cotton production in China are the hinterland of Shanghai—that is, the lower and middle valley of the Yangtze River—and from there northward into the fertile delta lands of the Hwang-ho. Although the production is so large that China ranks as one of the principal cotton countries, little is available for export. Domestic demand absorbs practically the entire crop. (Illus. p. 181.)

Russia. In Russia, cotton is grown extensively under irrigation on the fertile loess soils of Turkestan and in Transcaucasia. The total area has increased from less than 2,000,000 acres in 1910 to more than 5,000,000 acres just before World War II. Further expansion in both of these regions is probable but ultimately it will be limited by lack of available water. Most of the cotton is of the American upland type. In recent years considerable cotton has been grown also in the North Caucasus area, the Crimea, and in the area of the southern Ukraine.

South America. In South America the principal producing centers are in Brazil, Peru, and Argentina. In recent years Brazil has become a major cotton exporter, exceeded only by the United States, India, and Egypt. The expansion of cotton acreage has come not so much in the old cotton area of northeastern Brazil as in the coffee regions of São Paulo and in those of Minas Gerais. It is possible that the area suitable for cotton growing in Brazil exceeds that now so used in the United States. In Peru, long-staple cotton is grown in many of the irrigated valleys of the coastal desert.

Courtesy Board of Commissioners, Port of New Orleans

Bales of cotton being loaded in ocean-going steamer for export at New Orleans

International trends. Raw cotton is light, can be tightly compressed into bales, and does not spoil easily. As it can be shipped long distances at low cost, areas of manufacture need not coincide with areas of production, but manufacturers can seek locations where power, efficient machinery, and cheap labor are available. As a result of these factors, cotton has become an important article in world trade, and the United States has dominated the world market (Illus. p. 181).

Since World War I several countries, especially the United Kingdom and France, have been endeavoring to make themselves more independent of American cotton. In the African colonies of these two countries governmental encouragement is causing a slow but steady expansion of the acreage. In the Anglo-Egyptian Sudan, the [illegible] irrigation project, on the Blue Nile near Khartoum, has made possible the development of a new region, which produces mostly long-staple Egyptian cotton. In Uganda, American upland cotton has become an important crop. Cotton production is increasing in Nigeria, Kenya the Congo, Algeria, and French West Africa.

All regions outside of the United States have shown a decided upward trend since the 1920's. Nevertheless, this country still is the leading producer. Continued supremacy depends, however, not only on the favorable natural environment but also on cheap labor, or mechanized high-quality production, so that the crop can be sold on world markets at prices low enough to meet the increasing competition with other countries.

Centers of consumption of raw cotton. The principal cotton textile districts of the world are in Great Britain, the United States, Germany, Russia, France, Italy, Czechoslovakia, Belgium, the Netherlands, and other European countries. Other important cotton manufacturing districts have developed in recent times in Japan (Osaka, Nagoya, and Tokyo districts), India (Bombay and Madras districts), and China (Shanghai district).

The American cotton textile industry started in New England, where cheap water power and a good labor supply were available. For many years that section was the main industrial consumer of cotton. Since the turn of the century, however, the trend in cotton manufacture in the South has been sharply upward, particularly in the Piedmont districts from North Carolina to Alabama. As a result, the South has now far outstripped the North as a consumer of raw cotton. The old agricultural South has become a section where manufacturing interests compete for labor and for public favor with agriculture. This change is having profound effects, not only industrially but also socially and politically.

Peanuts

The peanut, thought of by most people as something to be bought in small paper bags and eaten at circuses and ball games, is a product of great commercial importance as a source of vegetable oil for the manufacture of cooking oils, oleomargarine, soap, and greasing oils and as an animal feed. Peanuts thrive best in soils of loose structure which are fertile and slightly alkaline. They grow, however, also on sandy soils where warmth and moderate rainfall prevail throughout a long growing season.

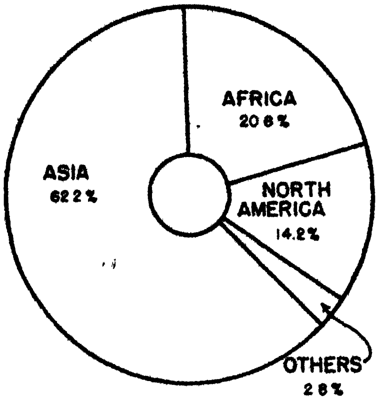
TABLE VII

PRODUCTION OF PEANUTS IN PRINCIPAL PRODUCING COUNTRIES

Countries	*In 1,000 Quintals of Unshelled Nuts*			
	1934-1938 Av.	1943	1944	1945
United States	5,397	9,910	9,574	9,263
Burma.	1,659	906	No data	1,148
China . .	25,157	26,617	26,879	26,939
India.	27,002	38,843	39,179	31,630
French West Africa. .	7,807	Data incomplete	Data incomplete	Data incomplete
Nigeria. . .	3,348	2,069	2,238	2,558
Netherlands Indies. .	2,408	No data	No data	No data

Source: *International Yearbook of Agricultural Statistics*, 1941-42 to 1945-46, Bureau of the F.A.O. in Rome, Vol. I, Rome, 1947.

Peanuts are produced in tropical and subtropical lands and even poleward of the subtropics. In the latter regions the seed remains smaller and the oil content lower. Important centers of production have developed in southern and eastern Asia, southeastern United States, and western Africa (Illus. above).



(A.) Peanuts. Percentages of total production by continents.

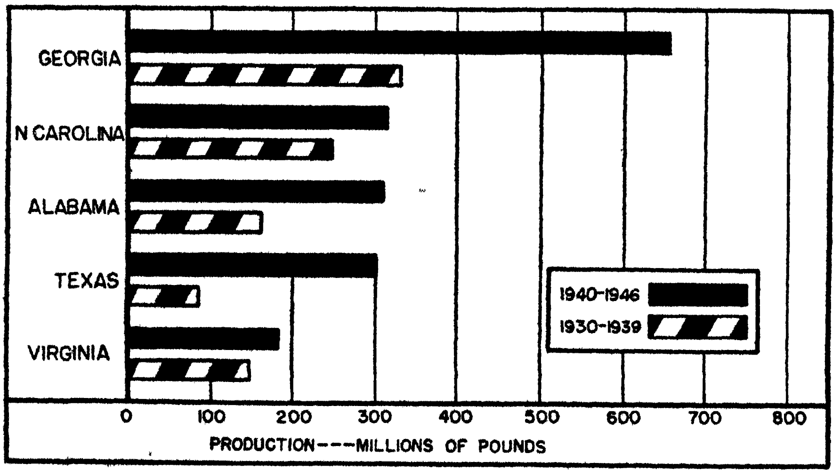
Principal exporting countries are India, Senegal, Manchuria, Nigeria, China, and Gambia. In India, production is favored not only by a dense population that uses peanuts as one of several sources of edible oils, but also by export markets in Europe.

Peanut growing has been fostered in western Africa by the French and British, whose tropical colonial possessions are considered natural sources of supply of edible vegetable oils needed by the home countries, which are short of fats. In China, peanuts have become a major cash crop in the Shantung area and adjacent portions of the country. The total annual crop of China is estimated at about 3,000,000 tons, of which from 100,000 to 200,000 are exported.

In southeastern United States peanuts are important in every state from Texas to Virginia, but outstanding production is found in Georgia, North Carolina, Virginia, Alabama, and Texas. The acreage has increased six-fold since 1899, one of the most marked increases shown by any crop. Recent figures have placed the total area in peanuts in the United States at over 4,000,000 acres with production of about one million tons (Illus. below).

Vegetables and Subtropical Fruits

In all the regions of humid subtropical climate the production of fruits and vegetables is important for local sustenance. Commercial production, however, has reached a greater development in southeastern United States than elsewhere, because the population centers farther north



(B.) Average U. S. production of peanuts by states, 1930-1939 and 1940-1946.

afford splendid markets easily reached by modern transportation facilities. On the coastal lands from Texas to Virginia, horticulture is the leading form of commercial agriculture. The profits from vegetables depend largely upon the possibility of marketing the products before they must meet the competition of those grown near the population centers farther north. Growers must, therefore, plant as early in the season as possible and risk the danger of frost. Potatoes from Florida and southern Texas run a close race with those from Cuba and Bermuda in reaching northern winter markets, with slightly later production coming from southern Louisiana, southern Alabama, and the coastal strip of South Carolina. Louisiana is the leading state in furnishing early strawberries. Southern Florida and southern Texas have developed a large production of early tomatoes.

Courtesy Florida Citrus Exchange, Tampa, Florida.

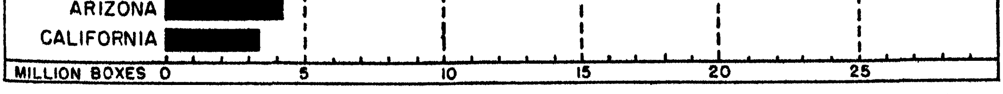
(A.) Grapefruit orchard with pickers at work.

Tree crops are primarily types that cannot be produced in the cold-winter areas. Hence, competition does not result in pressure for early production, except for crops such as Georgia-Carolina peaches.

In central and southern Florida citrus fruits occupy the center of the stage. There the severity of the winter cold waves is so modified by the warm ocean water on both sides of the peninsula and by the numerous lakes which dot the surface that large-scale production of the tender subtropical fruits is possible. Florida vies with California as an orange-growing state. Favored by abundance of rainfall, extensive areas of relatively cheap land, and large markets, expansion in this line is continuing.

Tung nuts produced for oil are becoming increasingly important in the Gulf States from Louisiana to Florida, centering in Mississippi.

Grapefruit. The peninsula of Florida with humid subtropical climate, and southern Texas, with an arid climate, are the world's foremost centers of grapefruit production; the two sections together account for over 80 per cent of the world's production (Illus. below). Other irrigated arid regions with important grapefruit production are Arizona, Palestine, and California. Tropical Puerto Rico also is a significant center. One of the remarkable developments in recent decades has been the tremendous increase in production and consumption of fresh grapefruit and canned grapefruit juice in the United States. In 1925 the total production of the United States was one-quarter million tons; in 1945



(B.) Grapefruit production in U. S. A., by principal states. Boxes weigh 68 lbs., California and Arizona; 80 lbs., Florida and Texas.

it reached the record figure of 2½ million tons. Small quantities are brought in from Puerto Rico, but exports far exceed imports. Most of the exports are directed toward Canada and the United Kingdom. Although expansion of grapefruit culture is reported from the West Indies and the other production regions mentioned, Florida (Illus. p. 189) and Texas will probably remain the principal centers of production in the Western Hemisphere because of abundance of suitable land, sufficient rainfall, or ample water by irrigation and less danger of loss by hurricane than in the West Indies.

Rice

Although accurate data are wanting, it is estimated that the world production of rice may safely be placed at about 1,500,000,000 quintals[1] of rough rice annually. On that basis the world's rice crop exceeds that of corn and in some years may well exceed that of wheat. However, the inedible portion of rough rice exceeds that of threshed wheat. Rice is a major food of the wheatless multitudes of the Far East and the Middle East, and is becoming increasingly important as a basic foodstuff in Caribbean America and parts of South America. In those regions rice is what white wheat bread is to the European, the most desirable but also a relatively expensive food

It is not known where rice originated in the dim past of early human progress. Wild species of rice are found in the wet swampy regions of southeastern Asia and tropical Africa. The principal species that was domesticated, *Oryza sativa*, has retained all the characteristics that indicate an original swamp habitat. There are numerous varieties of rice, each with its own particular characteristics and requirements, but all must have high temperatures in order to germinate, bloom, and mature. Some of the tropical varieties will not germinate at temperatures below 68°F., and the most favorable temperature is often considerably higher. Little rice is grown where average January temperatures fall below freezing point.

These temperature requirements make rice a crop of the tropics and subtropics. Within these climatic areas, the geographic distribution of the rice crop is limited by its heavy needs for water. It must have much water, both in and upon the soil The easiest way to supply the water is to irrigate and temporarily flood the land Unlike most other crops, rice does not require air for germination; therefore it finds a swamp habitat favorable for growth Rice is the only great crop that is grown on actually flooded fields (Illus. above). Some rice, the so-called "upland rice," is grown on dry, nonirrigable land, where it must depend upon precipitation, but this is possible only where rainfall is heavy. Even then the yield is meager, and if moisture should be a little below expectations, the crop often is a complete failure. Heavy, water-retentive soils, with a high clay and silt content, underlain by a hardpan that slows

Courtesy Philippine Trade Commission, Washington, D C

Terraced rice fields in the mountains of Luzon, Philippines up percolation, are most advantageous to rice.

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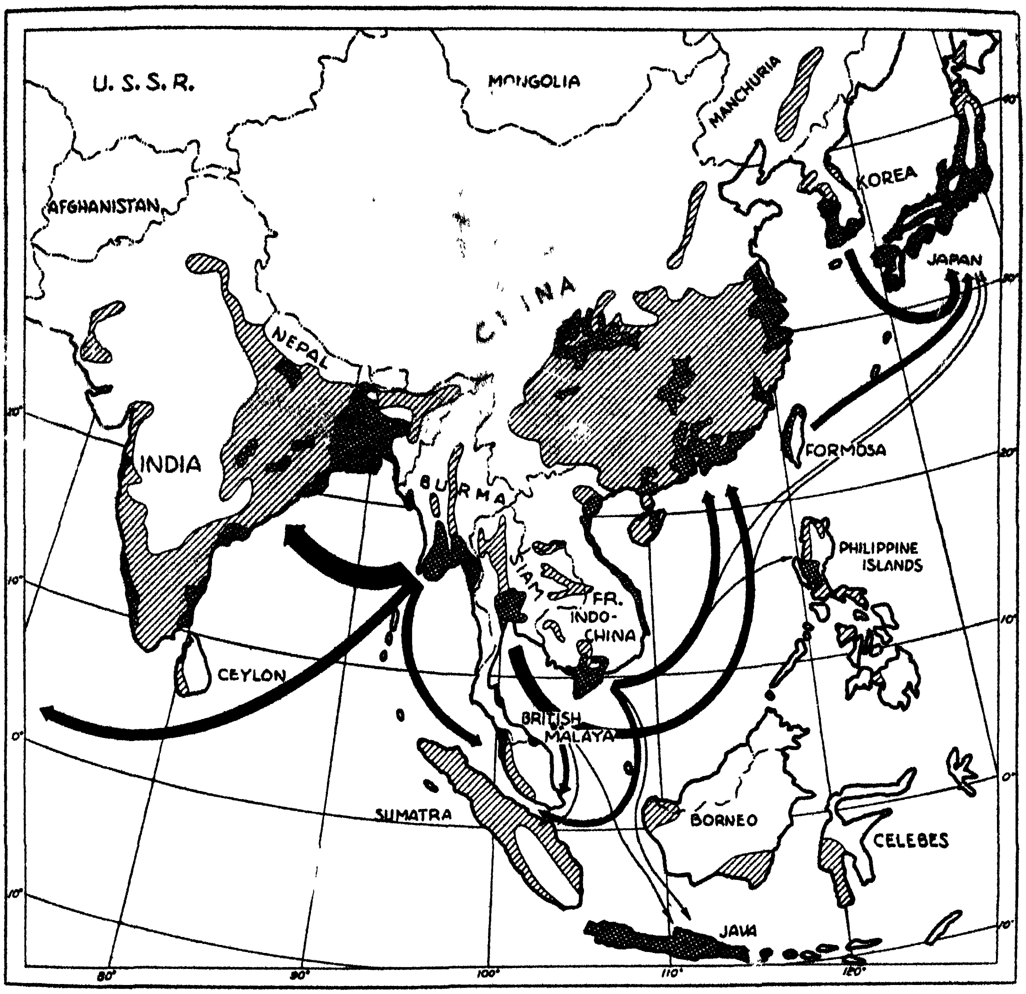
[1] One quintal equals 220 pounds; one hectare is 2.47 acres

Distribution of production. The climatic and water requirements have tended to limit the cultivation of rice to the great, gently sloping river lowlands, deltas, and coastal plains of tropical and humid subtropical regions, where soils are heavy, temperatures high, and moisture is plentiful. These factors, together with the demands for food to supply the dense populations, account for the extensive cultivation on the lowlands of southeastern continental Asia, Japan, Formosa, Java, and the Philippine Islands (Illus. below).



Principal rice producing regions and trade in rice.

Subsistence agriculture in the tropics, usually primitive and extensive, often even with migratory tendencies, has developed unparalleled intensiveness in those regions where rice is the principal crop. With primitive implements, but with an unending amount of care and an astonishing quantity of labor, the land is prepared and the rice crop is grown and harvested. The cultivation of rice represents tropical native agriculture at its best and in its most stable form.

Methods of production. With an unlimited expense of labor, the result of generations of effort, the land has been terraced and subdivided into small holdings. Each parcel is surrounded by a little dike to hold the irrigation water, which is admitted or pumped in at the upper side of the terrace system and led slowly from terrace to terrace until the surplus reaches the river below (Illus. p. 190). The individual rice fields, "paddies," or "sawahs," or whatever their local names may be, are prepared meticulously. They are ploughed into a thick, soft mud and carefully leveled. The primitive economy of the native farmer and the small sizes of the fields preclude the use of modern machinery. About the only kind of animal that can stand the rigors of labor and climate is the slow, poorly disciplined carabao, or water buffalo. The young plants, grown with utmost care and attention in nursery beds, are transplanted into the muddy field by hand. Cultivation and harvesting are likewise carried on almost entirely by hand labor.

Social relationships. Rice cultivation in the Orient—with the attention given individual plants and with the everlasting care for the maintenance of terraces, dikes, and irrigation works—is one of the most labor-intensive types of agriculture in existence; in many places it borders on true horticulture. Where the conditions of the natural environment are favorable, especially where an ample supply of water is assured, rice is one of the safest crops that can be grown. With sufficient water, crop failure is rare, although in some lowlands there always lurks the danger of destructive floods. In many sections two rice crops can be grown in the course of a year or one rice crop and one nonirrigated crop. This method of rice production thus makes possible a dense population and at the same time *requires* a dense population because of the amount of hand labor involved. The areas of great rice production are for the most part also areas where the density of population is far above the average.

Rice production is necessarily a stable industry, greatly dependent upon orderly, peaceful conditions, and therefore is likely to develop a highly conservative small peasantry, strongly rooted in the soil. The co-operation and organization that are essential elements in successful rice cultivation undoubtedly aided the early development of such civilizations as those of India and China.

No dietary habit seems to be more strongly entrenched than the eating of rice, and no agricultural habit seems to have become more strongly entrenched than the growing of rice. The peasant of the Indian lowlands, of Java, or of southern China tends to grow rice wherever he goes. This tendency may explain the cultivation of rice in areas which are seemingly on the extreme margin of profitable cultivation, as in northern Honshu, southern Hokkaido, north China, and Manchuria. The preference for rice coupled with the pressure of population and the absence of adequate transportation facilities may explain the staggering amount of manual labor expended upon the terracing of hillsides—and even of mountain flanks—in order to make them fit for irrigation and thus for "paddy" rice.

Western agriculture, which has always centered around the bread grains, has given relatively little attention to rice. In Europe, rice is raised in only a few areas, such as the plains of Valencia in Spain and of the Po in Italy. Here, with the aid of modern plant breeding and the scientific application of fertilizers, rice has been made to yield as much as 60 quintals per hectare. Average yields, however, are considerably lower—about 40 quintals per hectare for Spain and 30 for Italy. Other average yields are 26 for Japan, 18 for Egypt, 17 for China, 14.5 for the United States, and from 8 to 15 for most other parts of the Far East.

The areas where rice could be grown are much larger in North America than in Europe. In many parts of the warm, rainy South the natural environment is favorable; before the Civil War rice was grown with the aid of slave labor as far north as South Carolina. It has not, however, become an important crop in the southeast, because of the minor role it plays in the white man's diet and the amount and disagreeable type of labor involved in its cultivation. With modern methods adapted to American aims of high production per worker, rice is produced on the low, black coastal prairies of Louisiana and Texas, in the Mississippi lowland of northeastern Arkansas, and in the Sacramento Valley of California. These machine methods have been so successful that at present the United States produces more rice than it needs for home consumption, though rice has become a traditional part of the diet in French Louisiana. Because of the high quality and mass production of the American product, the surplus is exported in successful competition with that grown under primitive oriental conditions. ✓

World production and international trade. Since rice is grown on a small scale for local consumption, its international trade does not attain the importance of that in wheat. Nevertheless, world trade in rice has been growing steadily in recent decades and is of vital importance to the continent of Asia. ✓

In the densely populated areas of southern and central China, Japan, and Java, production is not sufficient to meet demands, even though part of the population is too poor to eat rice regularly. These are the principal importing countries, to which may be added the Philippines, Malaya, the Outer Provinces of the Netherlands Indies, and western Europe (Illus. p. 191). The Philippine Islands and the Outer Provinces easily could produce sufficient rice for domestic requirements, but the interest of the population lies more in the direction of cash exports. Nearly all countries of western Europe are importers of rice because their populations were taught its use when early colonial ventures made it available at comparatively low prices.

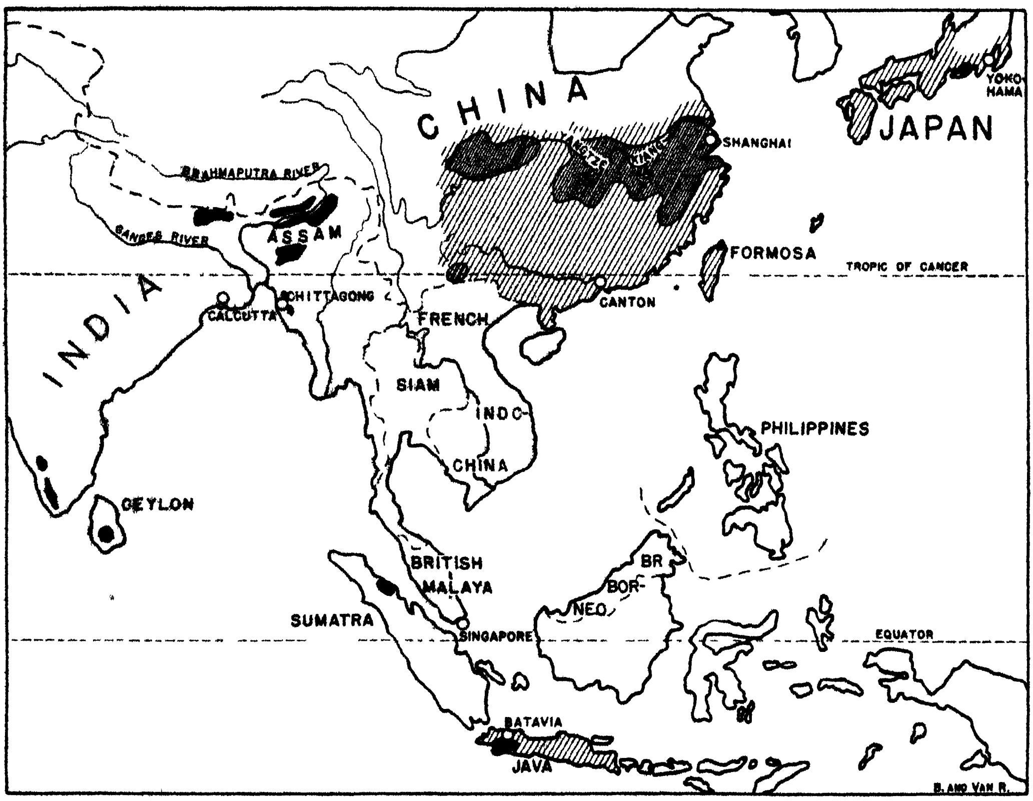
The regions of surplus production of rice (Illus. p. 191) are characterized by exceptionally favorable physical environment and by moderate density of population. India and Ceylon obtain most of their imported rice from Burma, as Japan obtained most of its imports from its former possessions, Formosa and Korea. ✓ French Indo-China, Siam, and Burma sell not only to other Far Eastern countries but also to Europe. A large percentage of the rice sold in the East is handled through and distributed by the two great entrepôt ports of Hongkong and Singapore. The only other oriental exporters that need be mentioned are Egypt and Iran. The producing regions in Europe and North America raise rice of excellent quality, and all have considerable quantities available for exports. Rice from the United States is exported to the island possessions, Puerto Rico and Hawaii, to Cuba and Central America, to Europe, and even to the Orient, while that of Italy and Spain goes to other European countries. The consumption of rice for food and for industrial purposes, such as flour and starch, has called a milling industry into life in several western countries. Since World War I, however, this industry has encountered a tendency for most of the milling to be done in the countries of export such as the United States.

Tea

The tea shrub (*Thea sinensis*) is a broad-leaved evergreen limited in commercial production to areas where there is no cold season. It is, however, tolerant of a wide range of warmth such as prevails in the tropical and subtropical regions. The tea bush has been known to survive as far north as southern France, and it can be grown in southeastern United States.

As the tea shrub is moisture-loving, its commercial cultivation is confined to rainy tropical and humid subtropical regions. The teas of commerce consist of the dried young leaves and tender sprouts of the shrub, and the necessary vigorous growth is possible only where rainfall is ample and dependable and the air constantly humid.

The tea industry requires an abundant supply of cheap labor. Plucking and preparing the leaves is a tedious task, and one that requires considerable skill. It is improbable that any kind of machine can ever be devised to perform this work. Successful tea plantations, therefore, can be established only where density of population is high and labor costs relatively low. These environmental and economic factors are responsible for the concentration of the commercial tea industry of the world in the countries of southern and eastern Asia. Minor centers of production are located elsewhere, such as in the humid subtropical portion of Transcaucasia in the Soviet Union.



Principal tea producing regions of the world and chief exporting cities.

Historical development. The necessity for extreme caution with drinking water and the practice of boiling it may be partly responsible for the early popularity of tea among the Chinese. From the Far East the use of tea spread to Europe and other parts of the world. From a luxury which only the wealthy could afford, it became a necessity and an important article of world trade. At present, production of tea for the world market is concentrated in India, Ceylon, the Netherlands Indies, China, and Japan (Illus. below).

There are two main varietal groups of the tea plant, the Chinese and the Assam. The latter was discovered wild by the British in northeastern India and has been domesticated. It grows taller and has much larger leaves than has the Chinese variety. While China and Japan grow the Chinese varieties exclusively, India, Ceylon, and the Netherlands Indies cultivate the Assam tea.

Distribution and commercial production. India is the principal tea exporter of the world. The industry centers in the flat, alluvial lands on either side of the Brahmaputra River and in the region immediately south of the Assam Hills. This part of the country has very high rainfall, averaging from 80 to 100 inches per year in the tea regions proper. High humidity, heavy dews, and morning fogs favor rapid development of young leaves. From December to February, however, this part of India has a cool season, at which time the shrubs remain dormant. During the remaining nine months leaves can be picked every eight or nine days. Another important tea area is in the foothills of the Himalayas, near Darjeeling, where the tea gardens lie at altitudes of up to 4,000 feet. Here the slow growth of the plant, resulting from lower temperatures, leads to the production of a high grade leaf. The yield per acre, however, is considerably less than in the lowlands. In southern India tea is grown along the rainy west flanks of the Western Ghats. There, and in neighboring Ceylon, plantations lie at greater altitudes than in Assam. No unfavorable season interferes with the growth of the leaves, and picking can continue throughout the year.

Tea is grown in all sections of Java, but production is most intensive on the fertile volcanic soils of the higher districts of West Java, where rainfall is plentiful at all seasons. In recent years the Deli district on the east coast of Sumatra has also become an important producing area.

The tea produced in India and the East Indies is of the black type, which requires fermentation of the leaf, along with withering, rolling, and firing. The Assam variety contains a high percentage of tannic acid (tannin), and although the fermentation process eliminates nearly half of this, sufficient is left to impart to the beverage a strong flavor and a certain pungency liked by Western consumers.

Chinese tea, grown principally in China, Japan, and Formosa, is more delicate than the Assam variety. It is made into both green and black tea. Green tea is that which is not allowed to ferment. In China, production centers in the hilly belts that surround the Yangtze basins. During the summer months the monsoons bring considerable precipitation to all of southern China, and this, together with high temperatures, favors the growth of young leaves. In most districts there are three harvests: one in the early spring (March, April) furnishing first-quality leaves, the so-called *Pekoe;* the second in the early summer (May, June) yielding leaves of medium quality; and the third in late summer (August, September), of decidedly inferior quality and not entering world trade.

Production is in the hands of small farmers who devote most of their time to the cultivation of foodstuffs and grow tea as a spare-time crop chiefly on sloping lands not suitable for other crops. The large number of miniature tea gardens and the nearly complete absence of modern plantations results in a heterogeneous product not so suitable for large-scale commercial methods of selling. Furthermore, the methods of manufacture are rather antiquated. As late as the end of the nineteenth century China was the world's most important exporter of tea, but the exports have declined greatly as a result of the competition of other areas which grow teas of stronger flavor.

In Japan, tea production centers on the Pacific side of southern Honshu, Shikoku, and Kyushu. This part of Japan has milder winters and receives considerably more rain from the monsoons than does the west coast. The growing season lasts from six to eight months and, as in China, three to four pickings are possible. Much of the tea is grown in the foothills and on higher terraces, where there is less competition from other crops. The exports consist entirely of green teas. Formosa is well known for its production of *oolong,* a semifermented tea.

Tea is a typically English drink. More than three-fifths of that which enters world trade is exported to parts of the British Empire. It is therefore logical that the principal tea trading center of the world should be in London, in the Mincing Lane district.

The only other country outside the British Empire with a high per capita consumption is the Netherlands. Although Russia is the land of the samovar, tea has remained a relatively expensive product. Most of the tea imported into the United States originates in India, Ceylon, and Japan. Minor quantities are imported from the Netherlands Indies and China.

Silk

Silk is by far the most expensive textile. It is a de luxe product which only the richer countries in the world can afford to buy in large quantities. The United States is the leading consumer. In China, the classical land of sericulture, the wearing of silken garments was long the exclusive privilege of the upper classes. Silk and spices, compact and valuable, were the principal products sent to southern and western Europe from the Orient during the Middle Ages. In many European countries of those times the use of silk in clothing was one of the prerogatives of the nobility and the higher clergy.

Silk is the product of the caterpillar of a moth (*Bombyx mori*) that spins itself a cocoon of silken threads when the time has come for its metamorphosis. This caterpillar, usually referred to as a silkworm, has the distinction of being cared for like a domestic animal. It feeds exclusively upon the young leaves of the mulberry tree, preferably the white variety. Sericulture, therefore, is directly dependent upon the cultivation of this tree.

Distribution and production. The white mulberry is primarily a tree of the humid subtropical climate, though it can be grown farther poleward. Only where the winters are comparatively short and mild, the summers warm, and moisture fairly abundant does it form young leaves in sufficient quantities to support large-scale rearing of silkworms. The trees are pruned into bush form in order to facilitate the gathering of the leaves. As the tree grows fairly well even upon poor soils, the mulberry groves can be relegated to rather mediocre sandy or gravelly areas, or to steep slopelands, thus leaving the better lands for food crops.

The rearing of the silkworms is carried on in the farm homes or in specially constructed sheds. Although in this way a certain measure of protection is provided against inclemencies of the weather, silkworms cannot be raised economically where it is too cold or too warm and humid. The silkworm needs temperatures that never fall below 60°F. during the breeding season; this limits their rearing largely to areas with a subtropical climate.

Large parts of the world are climatically suitable for sericulture. Southeastern United States, for example, has a climate in which both mulberry and silkworm can thrive. Nevertheless, sericulture is conspicuously absent from this country and from some other climatically suitable lands. The reasons are mainly economic and social. The rearing of silkworms is tedious work, requiring infinite care and patience and demanding vigilance both day and night. It can be carried on successfully only if a large amount of cheap, conscientious labor is available. Thus, the raising of silkworms is usually a family industry, carried on by the women and children of a crowded agricultural population, where the land alone cannot adequately support those living upon it.

China and Japan are the main silk-producing countries of the world. In China, the industry centers in the densely populated area west and south of Shanghai, in parts of the Szechwan basin, in the delta region of the Si-kiang near Canton, and in the Shantung Peninsula. So-called *wild* or *tussore silk*, the product of a caterpillar that lives on oak trees, is produced in the Shantung and Liaotung peninsulas. True pongee is woven from this kind of silk.

In Japan, sericulture is practiced as far north as Hokkaido. Most of the silk, however, is produced not on the fertile plains but on the steeper slopes of central Honshu, where good agricultural land is scarce and where population is so dense that means must be found to supplement the meager income derived from ordinary crops.

Although adequate statistical data are lacking, it appears that the continent of Asia produces nearly 95 per cent of all the silk in the world. Although China was formerly the principal exporter of silk, now, as a result of great improvements in sericultural practice and the expansion of its silk trade, Japan holds first place. Centers of minor production in Asia are Korea, Tonkin, India, Russian Turkestan, Persia, and the Near East. In Europe, silkworms are raised in northern Italy and a few other sections of the Mediterranean region. However, production in most of these European centers is slowly declining. In view of the enormous increase in the production of rayon and other artificial fibers, production of silk in Japan has remained remarkably stable. In 1938 world production of raw silk was estimated at 50,000 metric tons, of which Japan was credited with 40,000. In the same year the production of rayon and rayon staple fiber was estimated at 880,000 metric tons. The depression of the 1930's and the increasing competition of nylon seriously hurt the Japanese silk industry even before World War II shut off all sales of silk by Japan to the United States.

Processing. The silk cocoon may contain 300 to 600 yards of filament. The unwinding of the cocoons and the uniting of 3 to 10 filaments into one final thread of raw silk is called "reeling." This process requires great patience, dexterity, and attention to detail. In many regions, especially in China, the cocoons are reeled in the home. In the more advanced silk-producing centers, small reeling establishments known as *filatures,* with mechanical power, are scattered through the countryside, each one taking care of the cocoons produced in the neighborhood. The product of the filatures is known as *raw silk.*

At present, although silk textiles are widely manufactured in China and Japan for domestic use and even for export, probably half of the total production of raw silk moves from the producing countries to centers of manufacture in occidental countries. The manufacture of silk textiles depends not so much upon the availability of cheap power as upon the presence of a body of workers highly skilled in designing and manufacturing.

Since the American standard of living precludes production of silk here, the United States must import all of its raw material. It absorbs about 85 per cent of the raw silk exports of Japan, while smaller quantities are imported from China, Italy, and other countries. The manufacture of silk textiles is concentrated in Pennsylvania, New Jersey, New York, and southern New England. Important centers of manufacture in Europe are the districts around Lyons and Milan; smaller centers are found in and around Zurich, Switzerland, and Crefeld, Germany.

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Chapter Twelve

THE INTERMEDIATE CLIMATIC REGIONS: I. THE HUMID TYPES

BETWEEN THE BELTS OF ALL-YEAR warm climates and the all-year cold are belts marked by vigorous seasonal extremes, the areas of the "prevailing westerlies" or of the cyclonic storms, where we find the intermediate climates.

The belt in the southern hemisphere lies mostly over water, between the southern parts of the American, African, and Australian continents and the Antarctic continent. Only southern Chile, southern Argentina, Tasmania, and New Zealand are affected all year through by this belt. In the northern hemisphere the major land masses of North America and Eurasia are located within it (World Climatic Map). Meteorologically and climatologically the northern belt is far better known than the southern belt, and it is also of much greater importance. Thus, most of what is said here applies to the northern hemisphere.

In the regions of humid intermediate climates atmospheric circulation is complex. Cold air masses from the north meet warm air masses from the south in cold or warm fronts. This meeting of air masses, combined with the effects of the earth's rotation, results in the formation of large or small areas of low pressure—cyclones that move in a general west-east direction, interspersed with areas of high pressure—anticyclones—which have a similar, though often less rapid movement. The low-pressure areas move with an average velocity of from 30 to 35 miles per hour in winter and from 20 to 25 miles per hour in summer.

Fronts and cyclones are most pronounced and move farthest south in winter, invading the subtropical regions during this period. In North America, polar continental air masses—which are cold and relatively dry—develop in the north, and from there move southward, especially in winter. Polar maritime air, which is moist and cool, and in winter even rather warm in comparison with polar continental air, is formed over the area of the Aleutian Low. This type of air greatly affects the northwest coast of North America, but it is modified considerably when it moves over the Rocky Mountains and becomes not only drier but also warmer.

Tropical maritime air masses are formed particularly in the subtropical latitudes over the oceans. These air masses are warm and moist, and reach North America mostly from the Gulf of Mexico and the Atlantic Ocean. Similar air masses from the Pacific affect the American climate only to a relatively small extent. Tropical continental air masses are also of relatively small importance, as the only source for such air masses is northern Mexico, which is an insufficiently extensive land mass. Very warm and dry air of this type is formed in summer only, and is important in accounting for summer drought in southwestern United States. Thus, much of North America where the major portion of the people live is affected primarily by polar continental air masses and tropical maritime air masses. On the whole, continental air masses dominate the climate and thus, even immediately along the east coast, the American climate is continental rather than marine.

In Europe the opposite is true: as west winds predominate, the major invading air masses come from the ocean and consist of either polar maritime air or tropical maritime air. The former type brings moderate winter conditions to Europe, while the latter, having to go much farther than the tropical maritime air that reaches eastern United States, is not very warm, either in summer or winter. Polar continental air forms in the northeast, especially in winter, over the vast snow-covered land masses of eastern Russia and northern Asia. Thus cold weather in Europe comes from the northeast rather than from the northwest as in the United States. Tropical continental air does not play much of a role in the area of intermediate climates of Europe.

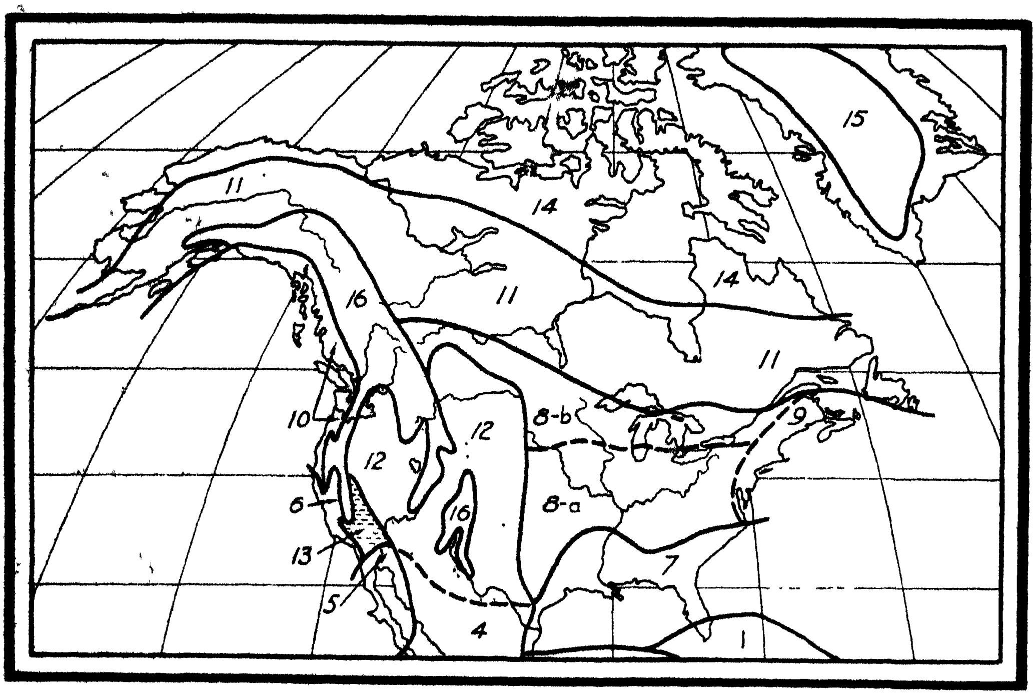
There are two major groups of climatic types within this belt: the humid and the dry. The humid climates have rainfall sufficient to promote a native flora of forest or tall grass; the dry climates have an annual rainfall commonly less than 20 inches and the native vegetation is of the steppe type, consisting of either short grass or scattered bush. In this chapter only the humid intermediate climates are considered. The humid intermediate climates are most typically developed in North America and Eurasia. In the Southern Hemisphere the middle latitudes are chiefly oceanic; the land masses are mostly tropical or polar. The occurrence of winter snowfall and the absence of a dry season are characteristic of all subdivisions of this climatic type, but the intensity and duration of winter cold and snow differ greatly. Principal contrast is between the continental interiors and the west coastal areas. The interiors of North America and Eurasia experience long, snowy, intensely cold winters, increasing in severity poleward, though summers are warm and sunny. Owing to the eastward drift of the atmosphere in these latitudes, the continental climate extends to the east coasts in a form slightly modified by the proximity of the ocean. The west coast, on the other hand, is dominated by the marine air masses moving in from the ocean, with comparatively little difference between winter and summer, and meager snowfall except in the mountains. Thus, the humid intermediate climates can conveniently be discussed under four subdivisions: (1) the *humid continental climate* of central and eastern Europe, northern China and Japan, central and eastern United States (see World Map of Climatic Regions, No. 8); (2) the *east coast continental* which is typical for part of the east coast of the United States and for part of Japan (see World Map of Climatic Regions, No. 9, and Illus. p. 200); (3) the *marine climate* of west coasts developed in western North America from Oregon to Alaska, which extends over considerable areas of western Europe (see World Map of Climatic Regions, No. 10, and Illus. p. 200); and (4) the *subpolar climate* which dominates much of Canada, Sweden, Finland, and northern Russia (World Map, No. 11).

All these types have rainfall sufficient to develop native vegetation of forest or tall grass and to support crop farming, where other conditions permit. The seasons are based on changes in temperature rather than on seasonal changes in the amount of rainfall. All have climatic conditions that appear to stimulate mental and physical activity.

The Humid Continental Climate

The humid continental type of climate is limited to North America and Eurasia. In the United States, this type of climate reaches from the subtropical South to southern Canada. In Europe, it predominates in southeastern Europe and Russia west of the Urals. In the Far East it is encountered in northern China, Korea, and Manchuria.

Temperature. The average temperature of the coldest month is below 42°F., but not more than four months have averages that drop below freezing. The average temperature of the warmest month is at least 36°F. higher than that of the coldest month; often the difference is even greater (Illus. pages 201 and 202). This large annual range generally does not cause serious discomfort, but on the contrary, is stimulating to mental and to physical activity.



Climatic Types in North America

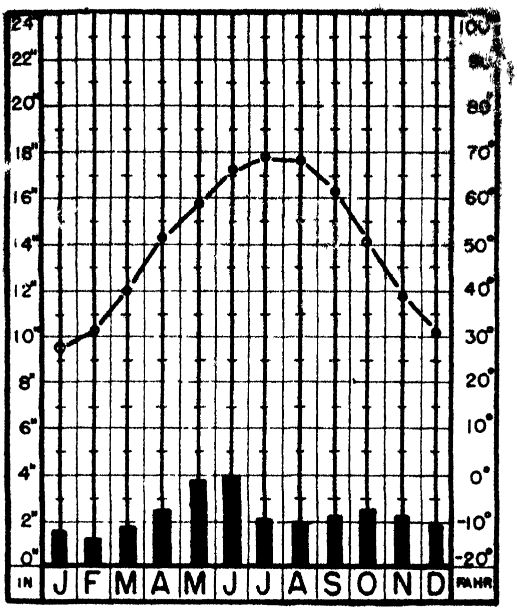
Legend·

1. Tropical Rainy Type
4. Tropical Steppe Type
   (includes subtropical type)
5. Warm Desert Type
6. Mediterranean Type
7. Humid Subtropical Type
8. Humid Continental Type
9. East Coast Continental Type
10. West Coast Marine Type
11. Subpolar Type
12. Middle Latitude Steppe Type
13. Middle Latitude Desert Type
14. Tundra Type
15 Ice-cap Type
16. Mountain Climate Type

The growing season varies in length from about 100 to 240 days. Light frosts may occur during the early and late weeks of this period, but ordinarily they are not injurious to the major crops. In the southern sections the winters are mild, but along the northern borders subzero weather is likely to occur during the coldest months. Toward the north the long, cold winters preclude the production of slow-maturing crops and the growing of fall sown grains. Throughout most areas periods of cool to moderately cold weather are likely to be interrupted by severely cold spells each winter. The areas most remote from the sea are characterized by periods of severe cold in winter and intense, sometimes devastating, heat in summer.

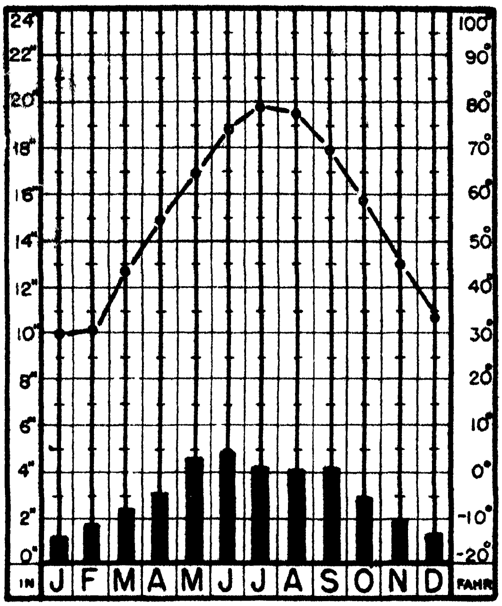
Winds and storms. In North America and Europe these areas are dominated by the cyclonic storm conditions of the prevailing westerlies.

The cyclonic storms are strongest in winter and their paths then lie farthest south. As a result, fluctuations of temperature are much greater in this season than during the summer months. Occasional cold waves sweep down across the American Middle West with such stormy violence that locally they are referred to as *blizzards*. On such occasions mild, balmy weather may give way suddenly to zero temperatures, a blinding snowfall, and piercing winds. During pioneer times people were often caught entirely unprepared, and personal suffering and serious losses of livestock resulted from these storms. With the development of weather warnings broadcast by radio, some of the danger can be avoided. Farmers and ranchers, thus forewarned, are usually able to provide feed and shelter for the stock while the storm rages. However, upon occasions, such as the winter of 1948-1949, blizzards of such intensity and duration occur as to still cause severe losses.



Short, cold winter climate. Average temperature and precipitation, Budapest, Hungary. Altitude 411 feet, total precipitation 26 inches

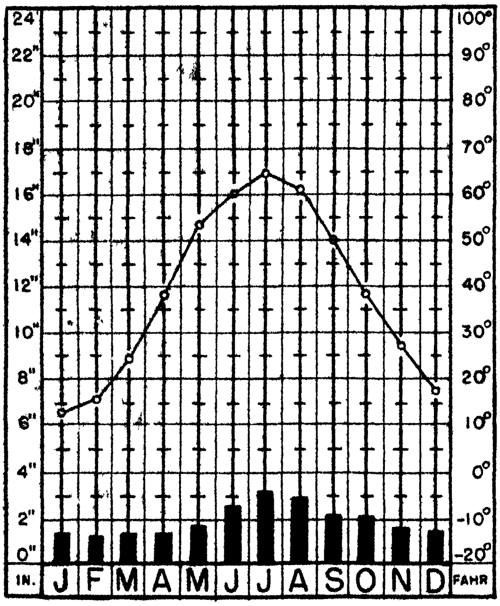
During the winter eastern Europe is under the direct influence of a large area of high pressure over the interior of Asia, which forces the lows coming in from the Atlantic Ocean to take a northeasterly course. These moving lows bring sharp changes of temperature to the Russian plains, often veritable cold waves and blizzards, there called *burans*. Occasionally the Asiatic high pressure becomes so pronounced that it extends far westward into European Russia, or even farther west. At such times prolonged periods of dry, clear, and cold weather may occur. In eastern Asia the monsoons dominate the weather, while cyclonic wind movements play a minor role. The high-pressure area of eastern Siberia causes strong out-blowing winds in winter, while in summer the pro-



Short, cold winter climate. Average temperature and precipitation, Kansas City, Missouri. Altitude 963 feet, precipitation 37 inches.

nounced low-pressure area gives rise to persistent in-blowing winds.

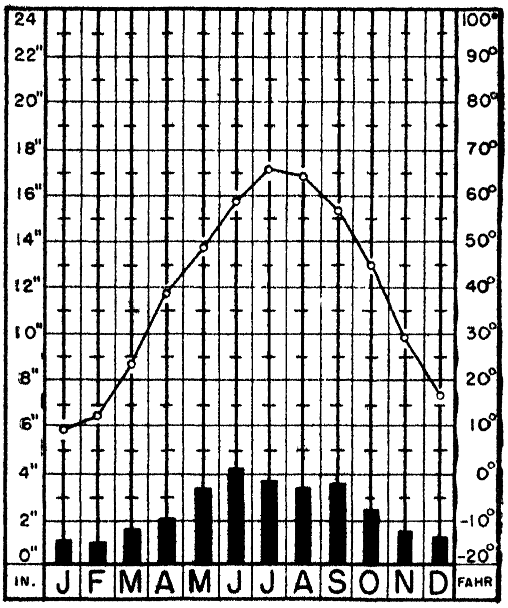
In summer the most feared weather phenomena, especially in the American plains west of the Mississippi, are the hot winds. Occasionally low-pressure areas centering in the upper Mississippi Valley move so slowly that they appear to be almost stagnant. Then southerly winds continue for days over the plains from Texas to the Dakotas, bringing with them soaring temperatures. When the land is dry, temperatures often exceed 100°F., occasionally surpassing 110°F., with blasting effects upon growing crops and serious damage to trees and grass. The summers of 1934 and 1936 were examples of the extremely serious effects of such winds when attended by continuous drought. In those years the corn crop of the United States fell to about half the normal.



Long, cold winter climate. Average temperature and precipitation, Moscow, Russia. Altitude 492 feet, total precipitation 24 inches.

During spring and early summer, when air conditions are unstable owing to the change from cold to warm season, small violently whirling air masses occasionally develop. These whirls, known as *tornadoes*, are among the most destructive storms known. Some tornadoes reach such wind velocities that only the sturdiest structures are able to withstand their attacks. Fortunately, the path of maximum destructiveness is seldom more than half a mile wide.

Precipitation. The average annual rainfall varies from about 20 inches in the drier areas to 50 inches in the more rainy sections. In general, the amount of rainfall varies inversely with distance from the sea. Summer maxima of rainfall are prevalent nearly everywhere, but decidedly dry winters are typical only of northern China and of the American interior west of the Mississippi. The well-developed summer maxima are very important in accounting for the successful crop agriculture of interior areas where the annual rainfall is only 20 to 35 inches; 65 to 75 per cent of it falls during the growing season. Toward the seaboard



Long, cold winter climate. Average temperature and precipitation, Duluth, Minnesota. Altitude 1,133 feet, total precipitation 29 inches.

the annual precipitation is greater and the seasonal distribution is more uniform. In the north the efficiency of rainfall is higher because of the lower summer temperatures and the briefness of the warm season.

In the comparatively dry areas where this type of climate adjoins the areas with intermediate steppe climate, such as in the American Plains and in Russia, variability of rainfall is great and particularly important because the effects of such variability are much more pronounced than in areas where the total precipitation is higher. Sometimes several years in succession may have rainfall so far above normal that streams overflow, wet weather ponds become all-year lakes, and lowlands are flooded for such long periods that crops are damaged or even ruined. Then many people, convinced that a great change in climate has occurred, start agitating for drainage projects. Under the impulse of such misguided notions many miles of unneeded drainage ditches have been constructed at great expense. Later on, when dry years come, as they inevitably do, either singly or several in succession, crop failures and pessimism go hand in hand. Many then believe that a permanent drought has set in and that the country is destined to become a desert waste. Instead of drainage, the construction of dams to impound water for irrigation purposes becomes the popular cry. In each situation, whether flood or drought, the popular mind is likely to be stirred by the immediate outlook rather than quieted by the facts of long-term records. Weather Bureau records and other evidence show that dry or wet years, or series of years, have come and gone in the past and doubtless will continue to come and go. Economic activities, agricultural and industrial, should be organized and operated in recognition of the fluctuating rainfall.

Native vegetation. The original vegetation of the areas with this type of climate consists principally of deciduous forest in the more humid sections and tall-grass prairie in the areas of lower rainfall. In China and Europe the land has been under cultivation so long that, except in the rougher mountain areas, little of the native vegetation remains. In the United States, the prairie was originally the conspicuous feature of the landscape from Indiana to central Nebraska and from Minnesota to the Ozarks of Missouri. Forest prevailed in the northeastern United States, principally of the mixed hardwoods type, with oak, hickory, chestnut, and ash predominating, with pine stand on some of the more sandy lands (Illus. below). Although the best agricultural lands, especially the prairie lands, have generally been put into cultivation, there still are tracts where the native vegetation covers the landscape.

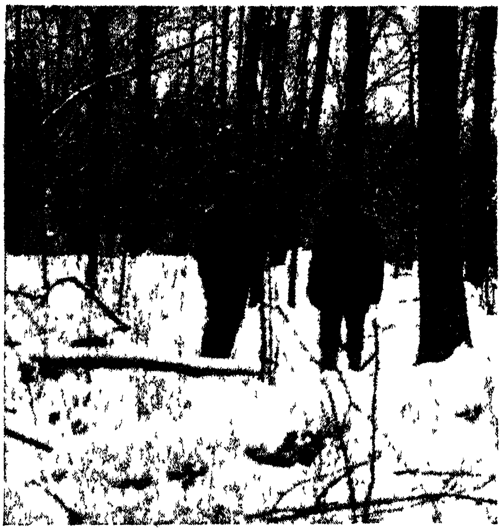


Photo by N A B

Deciduous forest of mixed hardwoods, northern Wisconsin.

Soils. The predominant soils are the gray-brown podzolic soils and the prairie soils. Leaching has not been quite so pronounced as in the soils of the humid subtropics, partly because of lower annual rainfall and partly because during the winter season the ground is frozen for some time, thus making the water in the soil inactive. The lower annual temperatures, and particularly the seasonal cold, account for less effective oxidation than in warmer climates, and therefore the soils are brown rather than red.

In the United States, this climatic region includes vast areas of plains where the soils have been developed from rocks of high lime content and where their structure still shows the beneficial influence of the former presence of lime even though leaching has removed most or all of the calcareous elements from the upper horizon. Such are the mature upland soils from central Ohio to central Iowa. These "calcific" types are characterized by a stable structure that enables them to remain in good physical condition under cultivation.

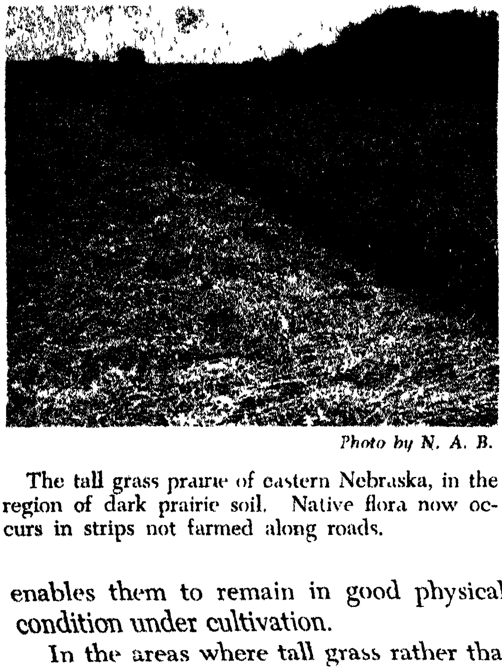


Photo by N. A. B.

The tall grass prairie of eastern Nebraska, in the region of dark prairie soil. Native flora now occurs in strips not farmed along roads.

In the areas where tall grass rather than forest prevail, deep, dark, friable soils occur. These are known as prairie soils, because they have developed under grass cover; their A horizons are deep, dark brown color, owing mainly to the high content of organic matter. Although the prairie soils are classified as pedalfers, because they are nonlime accumulating, they are but slightly leached and so are productive with little use of fertilizers. These soils are dominant from Illinois to eastern Nebraska and eastern Kansas and they include some of the best farmlands in the United States (Illus. left).

In the eastern and southern portions of this climatic region in the United States, where winters are generally mild and the rainfall is fairly heavy (40 inches or more), the soils are more thoroughly leached and the color is brown or gray-brown. The structure is quite stable; in fact the strong physical constitution of the soils is their greatest asset. Fertilizers are effective and hence need not be used in such large quantities as where weaker, less responsive soils are found. Still farther south in this climatic region, for example, in southern Missouri, Tennessee, and Virginia, we find the red and yellow soils of the South becoming dominant.

In the northern section of the region in North America, extending from northern Minnesota through northern Wisconsin, northern Michigan, and the adjacent portion of Canada to the Adirondacks, leached gray soils, known as *podzols*, are predominant. These soils also occupy much of the northern parts of this climatic area in Russia. The name is an old Russian folk term which has long been applied to these gray soils; it is derived from the words *pod*, or soil, and *sola*, meaning ash. The podzols are acid soils, deficient in minerals and well-decayed organic matter. The surface layer of the true podzols consists of raw, insufficiently decayed humus material, derived from needles of conifers, mosses, twigs, and leaves, and may reach a thickness of a foot or more. This layer really lies on the surface. The upper soil, the real A horizon which lies underneath this, is gray to white in color and highly leached of plant nutrients and sesquioxides, iron and aluminum compounds. The structure is simple, either platy or granular. The B horizon, or subsoil, is dark brown in color and compact, owing to precipitation of organic matter and the iron and aluminum compounds leached from the upper soil. This type of extremely leached soil fortunately is limited to the northernmost parts of the area under discussion. Farther south the brown soils mentioned previously in this chapter are not as badly leached, and the humus they contain is well decayed: they are podzolic soils, but not true podzols.

With only lime added, the more highly podzolized soils, if virgin, often yield fairly well for two or three years because of the plant nutrients found in the capping humus layer. This, however, is soon exhausted, and then heavy applications of mineral fertilizers are necessary to maintain productivity.

On the whole, the regions of humid continental climates are favored with soils of high agricultural potentialities. Although the soils are mostly pedalfers, neither leaching nor oxidation has been excessive, soil structures are quite stable, and the organic content is comparatively high. On most of the mature soils, particularly on the various types of gray-brown podzolic soils and on the podzols, manure and mineral fertilizers are needed. In the United States the quantities used west of the Appalachians as yet are not great (Illus. p. 319), but they are increasing steadily. Since the soils of this area are responsive to fertilizers, moderate amounts will suffice to maintain fertility. In fact, in this country many of these soils, though theoretically outranked in fertility by the pedocalic soils farther west, actually are of considerably higher productivity because of a more favorable rainfall regime.

General aspects of land utilization. Wide diversity of crops is characteristic of regions with this type of climate. In Eurasia corn is of major importance only in some of the Danubian countries, whereas in the United States it is a major crop. In China, wheat, millet, and beans are the principal subsistence crops of a great population. There, with the use of simple, almost primitive, equipment, agriculture is carried on by hand-labor methods. Production per capita is low, but all available land is fully used in order to support the masses of people dependent directly upon it, and the total production is large. Pressure of population upon the land is so great that no surplus can be produced. As a result, the peasants have few or no reserves and famine is frequent.

In Europe, wheat, rye, corn, root crops, and hay constitute the basis of a successful agriculture carried on largely by modern methods, but with machines of small size and simple design, compared with the larger and more complex equipment used on the more extensive farms of the New World.

In the United States, corn is king in a large part of this region (climatic type 8-a). From an American point of view, the short, cold winter—long, hot summer type may well be called the Corn Belt climate, because the area extending from Ohio to eastern Nebraska and from southern Minnesota to the Missouri Ozarks is by all odds the greatest corn producing region in the world. However, it is not a one-crop region. The farmers raise not only corn but also large quantities of oats, wheat, root crops, and forage, particularly legumes and they are large producers of livestock as well. South of the Corn Belt proper lies a zone of transition from the humid intermediate to the humid subtropical climate, which is also a transition zone from corn to cotton. There soft winter wheat is so important that it runs corn a close race for first place. Within this transition zone are located the famous tobacco-producing areas of Virginia, North Carolina, and Kentucky, *the greatest tobacco-growing districts of the United States.* North of the Corn Belt proper (climatic type 8-b) the transition to the long winter type is marked by a gradual increase in the importance of oats, soft spring wheat, root crops, fodder crops, and dairying.

In the northern portions of this climatic area crop production of cereals is limited almost entirely to those which can mature in a short season. Flax, barley, and spring wheat are the typical grain crops. Flax, grown only for seed in North America, is produced also for fiber in Russia. Sufficient moisture during the earliest period of growth, large accumulated temperatures during the long days of the short growing season, and warm, dry weather during the harvest season are factors favorable for the production of wheat and barley of excellent quality. Rye is the fall-sown grain. Corn is grown chiefly for silage or fodder because of the danger that it will not reach maturity. Some legumes, especially clover, and tame grasses are important fodder crops. Root crops do especially well in this climate. In regions where little or no corn is raised, potatoes not only are a staple food for people but also are used extensively as feed for livestock. Some districts are important for sugar beets. The yield per acre is generally less than where the summers are long, but this is offset by the higher sugar content which results from the long periods of daily sunlight in summer.

The East Coast Continental Climate

Along the east coasts of North America and Asia between 35° and 50°N. latitude, the humid continental climate is somewhat modified by proximity to the ocean. It is well developed in North America from New Jersey to Newfoundland and along the Asiatic Coast from central Honshu northward (World Map of Climatic Regions and p. 201).

Temperature. Average temperatures are about the same as those in the corresponding latitudes of the continental interiors, but seasonal extremes are more moderate. For example, Eastport, Maine, has an average January temperature of 21°F. and an average July temperature of 60°F. St. Paul, Minnesota, in about the same latitude, has an average 9° lower in January, while its July average is 12° higher than that of Eastport. Spring arrives later in east coast climatic regions than in the interior, the last, killing frost usually occurring two or three weeks later. Autumn is also retarded, but usually not so much as the spring.

The seasonal range is considerably greater than in the west coast marine areas. The annual average temperature at Portland, Maine (46°F.) is only 6°F. lower than that at Portland, Oregon, in approximately the same latitude, but the January average is 17°F. lower, and the July average is 1°F. higher. Thus, on the windward coasts the summers are almost as warm but the winters are not nearly so cold as those on leeward coasts in higher middle latitudes.

Winds. When winds are from the east they bring to New England and maritime Canada quantities of damp air from the ocean which give rise to periods of piercingly chilly weather in winter. In summer the winds from the ocean are cool and pleasant along the shore, but, because of their high moisture content, they tend to become oppressive and enervating farther inland where land temperatures are higher. New York and Washington, D. C., have a number of notoriously uncomfortable, hot, humid days every summer.

Rainfall and humidity. The precipitation, which generally amounts to 40 to 80 inches annually, is distributed quite evenly throughout the year. The amount of precipitation is particularly noticeable in the winter snows; in New England the snowfall may exceed 80 inches in a single season, with much of it remaining on the ground for three or four months. Northwestern Japan, too, has heavy winter snows. In Japan, however, there are sharp contrasts between the east and west coasts. The west coast of Honshu receives its maximum precipitation in early winter as a result of the winter monsoon from over the Sea of Japan, while the east coast has heaviest precipitation during the summer monsoon with September the rainiest month.

Vegetation. The native vegetation characteristic of this type of climate resembles that of the adjacent, more continental climates. In America, deciduous forests—consisting either of an oak and poplar association, or, farther north, of an association of birch, beech, and maple—are prevalent on the lower and better lands (Illus. p. 207). Pines are concentrated on the sandier soils, while at higher elevation spruce and fir appear. Where forests have not been cleared, logging and lumbering are important. Another activity of economic importance in New England and New Brunswick is the gathering of maple sap and the manufacture of maple sugar and syrup.

In northern Japan, deciduous forests prevail—beech, maple, and oak being the principal trees. The many different kinds of maple are especially responsible for the beautiful autumn landscape for which Japan is justly famous. In the mountains, coniferous forests are dominant.

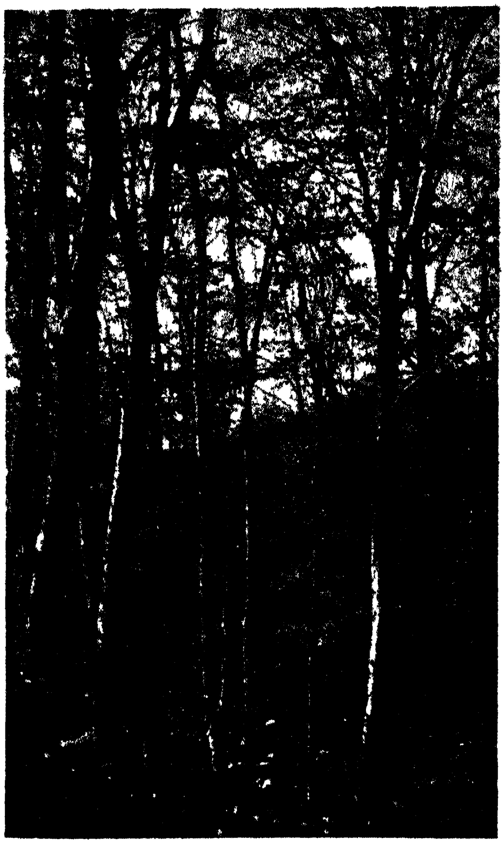


Photo by N. A B.

(A.) Mixed hardwood forest of southern New Hampshire.

Soils. In the lower and warmer sections, from the coastal area of Maine to Maryland, brown and gray-brown podzolic soils are the most common mature soils, while in the New England uplands and adjacent parts of Canada, podzols predominate. Alluvial soils provide the basis for the limited but successful agriculture practiced in the latter regions. In Japan, gray-brown soils prevail in the south and podzols in northernmost Honshu and Hokkaido.

Land utilization. The use of the land is influenced to a great extent by the relatively low temperatures which prevail in many areas. Coolness and cloudiness are handicaps to the complete maturing of certain crops, in the northern sections especially. In general, the summers are too cool for corn to mature, although some of the finest green corn for human use (sugar corn from Maine) is grown in this climate. Corn is produced also for fodder and ensilage. In the northern part of this climatic region wheat will not ripen satisfactorily, but oats and rye, both of which are well adapted to cool and humid environments, are produced successfully. Potatoes, vegetables, and fruits are important in subsistence agriculture, and where markets are available they constitute major cash crops. Aroostook County, Maine, for example, is famous for its potato production. Cranberries are grown in such abundance that Massachusetts and New Jersey furnish the entire nation with most of its supplies of that fruit. The ample precipitation, including winter

Photo by N A. B.

(B) The Coolidge farmstead, Plymouth, Vermont. Mixed farming in valley, higher slopes forest-covered.

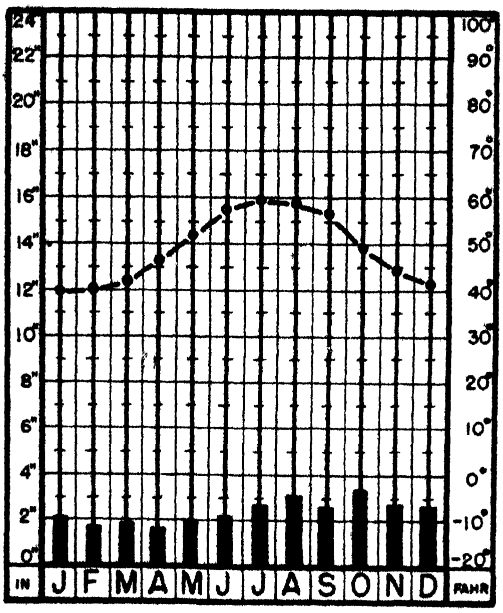
snows, and the lack of extreme summer heat and winter cold, favor the successful apple orcharding of New England and Nova Scotia. Most farms have woodlands on their poorer portions (Illus. B, p. 207).

The east coast humid continental climate has sufficient changes of temperature to be bracing and invigorating. It has fewer extremes of summer and winter than have the continental interiors, but there is enough change to avoid tiresome monotony of weather.

The West Coast Marine Type of Climate

Two areas in the Northern Hemisphere have a well-developed marine climate: the west coast of North America, from San Francisco to Alaska, and northwestern Europe, from Portugal to Norway (see World Map of Climatic Regions and Illus. at right). In the Southern Hemisphere this type of climate occurs in Chile, from Puerto Montt to Cape Horn, and in New Zealand. Of course, conditions vary considerably through such a wide range of latitude, but moderate temperatures and abundant rainfall with winter maximum prevail throughout. Where lofty mountains occur near the coast—as in North America, Chile and Norway—the marine conditions are strikingly developed in the narrow regions along the coast and on the lower mountain slopes. In Europe, south of Norway, the lack of a high mountain barrier permits the oceanic influence to be carried far inland, but with diminishing intensity. Naturally the rainfall is heavier, and seasonal temperature extremes are less on the windward slopes than on the leeward slopes of low mountain ranges, such as the Pennines of England.

Temperature. The significant feature of this climate is the small range of temperature during the year, owing to the tempering influence of the westerly winds blowing from over the oceans. The difference between the average temperatures of the warmest and coldest months ranges from 18 to 36 degrees Fahrenheit (Illus. below). Winter and summer are, of course, warmer in the lower latitudes than farther poleward at places equally near the coast. At Lisbon, for example, the average temperature of the warmest month is 70°F., of the coldest, 49°F.; at Copenhagen, 62° and 31°; at Bergen, 58° and 34°. Mild winter temperatures extend surprisingly far poleward in this climate. Even far beyond the Arctic Circle in Norway the winters are so mild that the coastal waters remain unfrozen throughout the long winter months.



Marine west coast climate. Average temperature and precipitation, Liverpool, England. Altitude 99 feet, total precipitation 28 inches.

Winds. The weather is dominated entirely by the numerous masses of maritime air that move in from the sea, accompanied by low-pressure areas. The passing of these lows causes constant shifts of wind direction and wind strength, resulting in highly variable weather. Nevertheless, winds from westerly directions are by far the most frequent—from the southwest during the winter months, and from the west and northwest during the summer. The stormiest conditions prevail along the west coasts of Scotland, Norway, and southern Chile; the last named faces the highly developed westerlies of the Southern Hemisphere known as the "roaring forties."

The southwest and west winds bear the tempering influence of the sea across France and Germany into Poland and even Russia, though with increasing distance their effects become less pronounced.

Rainfall. Rainfall varies with local conditions and with latitude. Where there are high mountains back of the coast—as in British Columbia, Washington, Norway, and Chile—heavy rains or snows fall on their western slopes. Although at higher latitudes, as in Alaska and northern Norway, the total annual precipitation is lower, more accumulates as snow, thus giving rise to a snow-covered landscape that persists for many months of the year and even creates some glaciers.

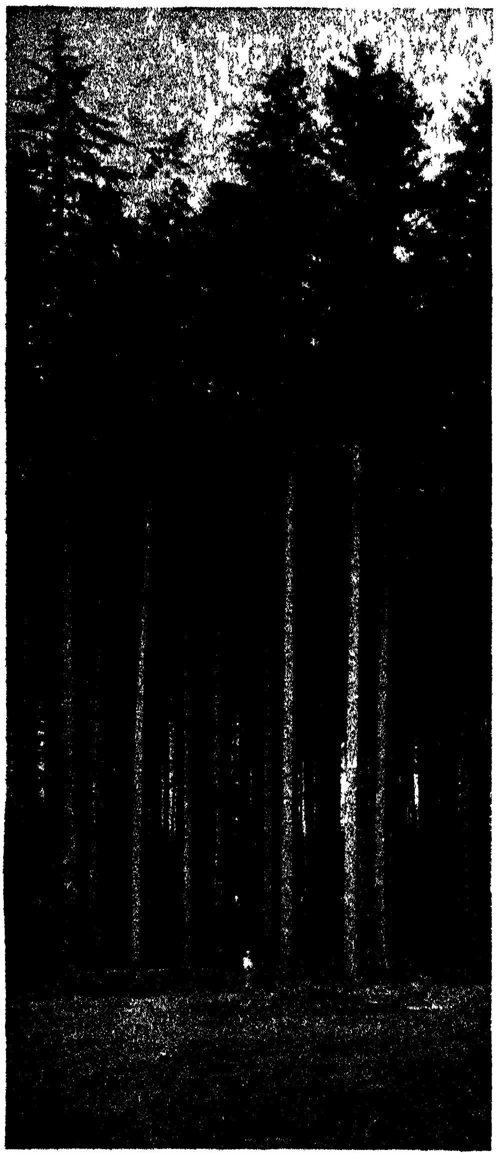
The rain does not fall in sudden heavy showers, but rainy weather may last for days, sometimes even for weeks. The rainfall is quite evenly distributed over the year with a slight maximum during the autumn and winter months, with spring and early summer the seasons of least rain. Cloudiness and fogs are common. In northern Scotland, for example, the period of unclouded sunlight averages less than an hour a day in winter. All of northwest Europe has much cloudy and rainy weather, especially in the fall and early winter. Sometimes the sun may not be seen for weeks, and umbrellas, raincoats, and overshoes are always needed. These typically marine conditions of prevalent cloudiness and autumn rainfall maximum change with distance from the ocean. Eastern France, Germany, and southern Sweden have a slight maximum in summer and clearer skies than the British Isles or Brittany.

The high humidity causes the winter cold to be sharp and piercing, even when the thermometer may stand well above the freezing point. In summer it often causes extremely muggy weather; then temperatures of 80°F. may cause quite as much discomfort as those of 100° in the Great Plains of the United States.

Native vegetation. The mild west coast climatic regions have or have had heavy forest covers. Dense stands of timber, mostly firs, characterize the western mountain slopes from California to Alaska, one of the most heavily wooded regions in the middle latitudes and at present one of the world's principal centers of lumbering (Illus. A and B, p. 210). The southern Chilean coast, where not too rocky or too boggy, likewise has heavy stands of timber, as yet little exploited. With the exception of parts of the British Isles, where the strong west winds hamper tree growth and the high precipitation favors the development of moors, most of northwest Europe once was heavily forested with deciduous hardwoods and conifers. However, the lands suitable for agriculture were cleared long ago and put into grass or tillage. In England but little forest remains, and on the continent forests are limited mostly to the mountains and to very sandy areas. None of them are original stands. Southern Norway has extensive stands of spruce and fir, but the northern part has few trees, because of long seasons with land temperatures below freezing.

Soils. In the mountainous areas along the coasts of North America, Chile, and Norway, agricultural soils are limited to the valley lands. Only a small percentage of the total area is arable. These lands, which are wholly alluvial, vary much in different localities, but the gray-brown podzolic types seem to be most common. The soils are young, and where drainage is adequate and texture favorable to cultivation they are usually quite fertile.

Northwest Europe is the only region of marine climate where a large percentage of the land is used for tillage agriculture. The mature soils are predominantly gray-brown podzolic soils, with well-developed podzols on some of the sandier lands. The structures of the former are fairly stable, and crop yields are readily increased by the application of mineral fertilizers. Among the best soils are those developed upon the alluvial deposits of the valleys and upon the recently emerged marine deposits along the coasts, as in the Netherlands and parts of southern Sweden. Glacial deposits mantle much of the land which borders the North Sea, with soils varying in productiveness from the nearly sterile sands of parts of northern Germany to the fertile loams of eastern England and the Danish islands. Farther south, nonglacial soils occur, varying in quality from medium to good. On the whole, however, the soils of northwest Europe are favorable to agricultural development, although heavy application of fertilizer is necessary (Illus. p. 318).



Courtesy U S Forest Service

(A.) Farm forest of Douglas fir in Oregon

Land utilization. In North America and Chile, the forest is the principal asset of the regions which have the west coast marine type of climate. The valley lands of the Pacific Northwest are important centers for grazing, dairying, and truck farm-

Courtesy U S Forest Service

(B.) Mixed stand of White Pine, Douglas Fir, and Engelmann Spruce, Cascade Range of southern Washington ing. The principal agricultural region here is the Puget Sound-Willamette lowland. Vancouver, Seattle, Tacoma, Portland, and smaller cities mark urban districts which give rise to profitable markets, especially for bulky or perishable products that cannot be shipped long distances.

In Europe, the region with a marine west coast climate shows considerable climatic diversity. In the south, all seasons are comparatively warm and mild; in the north, all seasons are cool, so cool that only the hardiest crops survive. In Scandinavia the change from marine to continental conditions is abrupt; in the lowlands of Germany it is gradual. The west coasts of Ireland and Great Britain are cloudy and rain drenched, the east coasts have more sunshine and a moderate rainfall. Under these conditions it is little wonder that agricultural diversity is pronounced. In southwestern France vineyards abound, while in Norway only hay and hardy crops such as rye and barley can be grown (Illus. above). Because of high rainfall, oats is the principal grain in the western and northern parts of the British Isles, while wheat leads in eastern England and in France. Potatoes constitute an important phase of crop agriculture in many parts of this region, especially in the Netherlands and Germany, the latter usually ranking foremost among all countries in amounts raised. Poland, also, although not wholly within this type of climate, is a great potato-producing country. The abundance of natural grasses and root crops, and the large markets furnished by the industrial centers within this region, favor the development of the dairy industry. The renown of the Netherlands and Denmark as dairy countries rests upon the secure basis of a favorable natural environment, skillful operation by intelligent and industrious farmers, and proximity of markets which insure profitable outlets for the products.

Photo by N A B

Haying scene near Narvik, Norway On account of high humidity, newly mown grass must be hung over trellises in order to be cured into hay.

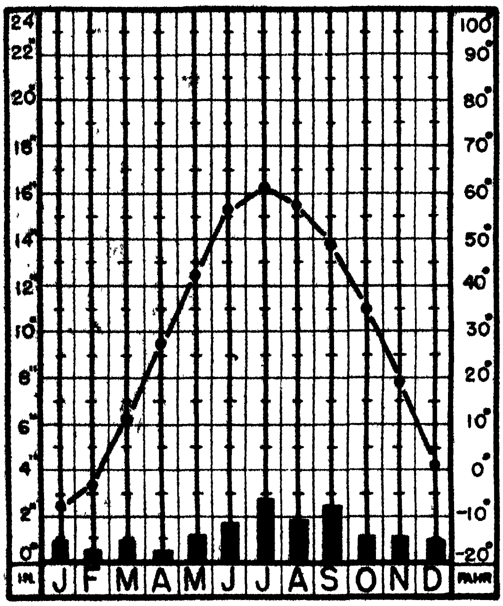
Viewed as a whole, regions with the west coast marine type of climate are lands of forest wealth, agricultural diversity, and industrial achievement. Climatic conditions are sufficiently varied to be stimulating, but not so extreme as to be enervating.

The Subpolar Type of Climate

Poleward from the other intermediate climates lies a belt of transition that practically coincides with the great belt of northern coniferous forests which girdles the Northern Hemisphere. The subpolar type of climate dominates northern Sweden and Finland, northern Russia, most of Siberia, central Alaska, and much of Canada. Within this belt a winter landscape of somber dark green and cold, dreary white is predominant for nearly nine months of the year. During a brief summer period of nearly continuous daylight, nature bursts into life with grasses and multicolored flowers which carpet the ground wherever the forest is not too dense to exclude them. Trees put forth new leaves. Insects and birds appear in swarming numbers, enlivening the short summer season by their hum and song and busy activities.

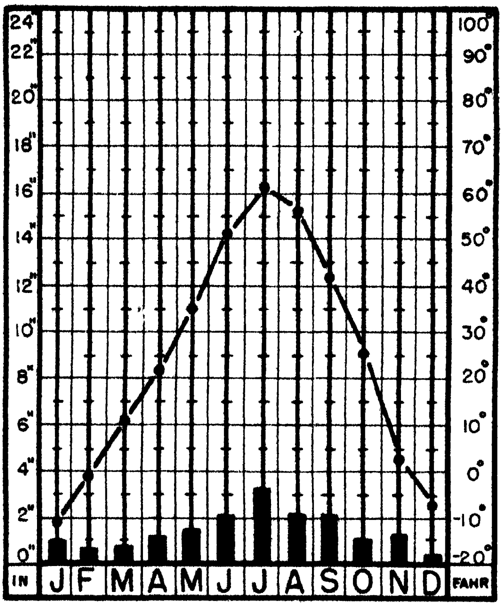
Temperature. While climatic conditions vary considerably within the subpolar regions, the long, intensely cold winter is common to all. Average temperatures of

50°F. or above are reached less than four months each year, and even in the warmest season light frost may occur at night, although day temperatures may be favorable for plant growth. The native vegetation, therefore, consists of plants that are cold-tolerant and able to utilize a short and rather unsafe growing period. Crops must be hardy and ripen quickly; in the far north, barley is the only grain crop that gives satisfactory yields. The soil and subsoil are free of frost during the midsummer period, a factor of great importance to the development of the forests that prevail over most of the subpolar climatic regions. The high annual range of temperature is another marked characteristic (Illus. above); the hottest summer days may exceed 90°F., whereas in the dead of winter the temperature may drop to —60°F., or even lower.



(A.) Subpolar climate. Annual temperature and precipitation, Fort Hope, northern Ontario, Canada. Altitude 1100 feet, total precipitation 16 inches.

Winds and storms. The regions of subpolar climate lie along the northern margin of the belt of prevailing westerlies. Cyclonic storms reach these regions in summer, particularly central Canada, northern Russia, and western Siberia. In winter, masses of cold continental air often originate here and spread outward. At all seasons weather is subject to sharp, sudden changes. While in most places travel is easiest in winter, because the bogs and rivers are then frozen and the land is snow-covered, severe gales and accompanying low temperatures often bring hazards.



(B.) Subpolar climate. Annual temperature and precipitation, Beresov, Siberia. Altitude 100 feet, total precipitation 18 inches.

Continentality of climatic conditions reaches its climax in Siberia, east of the Yenisei River. Pressure is abnormally high there during the winter, atmospheric disturbances are infrequent, and the air is calm; as a result, temperatures often fall below the freezing point of mercury, —39°F., but the dryness of the air and the absence of strong winds contribute toward making such temperatures bearable. A distinct disadvantage, however, is the lightness of the snow cover, or its absence. Summer temperatures, on the other hand, may be surprisingly high. At Verkhoyansk, the so-called "cold pole of the earth," summer temperatures of above 90°F. have been registered. In central Canada temperature extremes are not so great as in Siberia.

Humidity and precipitation. The precipitation is comparatively light, with a distinct summer maximum. Few places have an average of more than 20 inches per year. Because of the low temperatures which prevail most of the time, the relative humidity is fairly high and the rate of evaporation is low. The summer rains and the melting winter snows supply sufficient water for the vegetation which flourishes through the short season. Where the growing period is less than three months long, precipitation of 15 inches is ample, whereas in lower latitudes semiarid conditions would result. The winter snowfall, even where light, ordinarily accumulates so that for several months each year the landscape is white-blanketed, without interruption by warm spells such as produce the well-known thaws of more southern climes.

Native vegetation. The regions of subpolar climates coincide roughly with the great belt of the northern coniferous forests, known as *taiga.* Spruce, fir, and larch are the dominant species. Only a few of the hardiest deciduous trees, such as birches, poplars, and willows, are found, and they only in sheltered places along stream courses or intrenched valleys. Growth is slow because of the very short period wherein sunlight, warm air, and soil combine to favor plant growth. Tree roots commonly are shallow.

Over the southerly portions of these regions in Canada and Eurasia, forest is continuous and fairly heavy (Illus. right). In its undisturbed condition, much of the taiga forms a dense jungle of standing and fallen trees intertwined with mosses. Toward the northern border the forest becomes scattered and scraggly as it approaches the limit of tree growth. Where local conditions are relatively favorable, a prong of forest projects northward; where they are unfavorable, only shrubs or a mixture of shrubs and stunted trees survive. It is the margin of the coniferous forest where neither tree nor moss can claim supremacy (see Illus. p. 214). North of it is the treeless tundra.

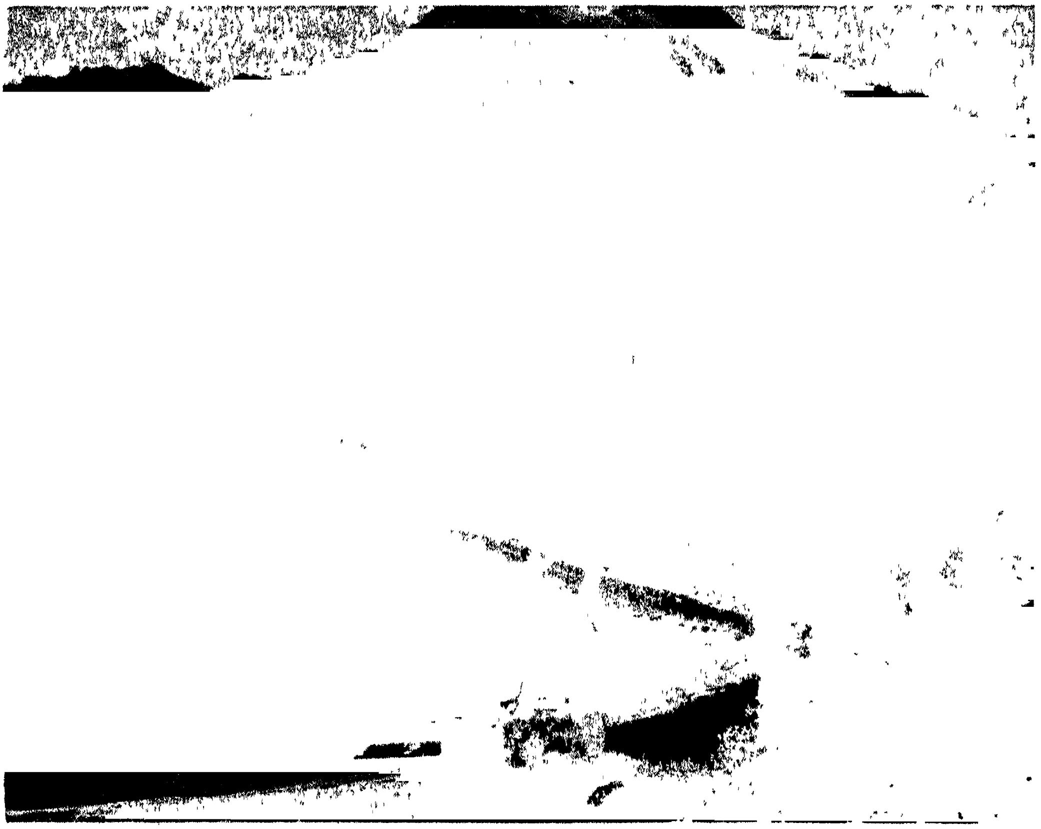
Soils. The soils are podzolic. A forest litter covers the upper horizon, and under it lies the well-known very light gray layer leached of its solvent minerals and organic matter. The soils are, however, of but little significance, as the climate is the direct factor which practically controls the type of human activities which may be practiced. The agriculturally important soils are limited almost entirely to the immature alluvial lands bordering streams and lakes.

Courtesy The National Film Board, Canada.

The northern coniferous forest along the Trans-Canada Highway between Hearst and Geralton, Ontario.

Land utilization. On the whole, in the regions of subpolar climates man's cultural landscape has not made great inroads upon the natural landscape. Such agriculture as is practiced is distinctly of the patch type and is almost wholly for local subsistence purposes. Barley, of the hardiest kind, is the chief cereal grown, although some rye is produced in a few districts along the southern margin. Potatoes do quite well and serve as an important foodstuff in some areas, particularly northern Sweden, Finland, and Russia. Hardy vegetables and quick maturing berries play a local role.

The forest is the principal resource. It has not yet been widely exploited in North America because other forested areas are closer to markets, but with their depletion will come increasing demands upon the resources farther north (Illus. below). In Norway and Sweden exploitation is carried on profitably, coupled with a replanting program that has won wide acclaim. Russia has vast forest resources within the subpolar climatic region, and while some use is being made of them, their full exploitation must await the establishment of better facilities for transportation than are now available.



Courtesy The National Film Board, Canada.

The northern coniferous forest along the Alaska Highway in northeastern British Columbia.

The northern coniferous forest to date has been of less economic importance for its trees than for its furs. The fur-bearing animals of Canada, Alaska, and Siberia have long provided the essential raw materials for the world's finest fur coats and scarfs. The activities of hunting, trapping, trading, and transportation serve as the basis of existence for some of the oldest and best-known corporations in the world, among which the Hudson Bay Company is conceded premier position in North America.

On the whole, the subpolar regions are characterized by such climatic hardships that they must be classified as unfavorable to human progress. They contain resources of vast possibilities, but exploitation awaits demands from without these regions. Their fur resources have long been exploited successfully, but markets have been and are now almost entirely where climatic conditions are less severe. The forests will become increasingly important as sources of pulpwood and structural timber for the lands to the south. Exploitation of mineral wealth will probably progress along similar lines. In Sweden, Finland, and Russia the southern portions of this belt have been developed to a greater degree than elsewhere.

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Chapter Thirteen

THE INTERMEDIATE CLIMATIC REGIONS: II. THE SEMIARID AND ARID TYPES

In the middle latitudes, dominated by the prevailing westerlies, the dry lands are found only east of high mountain ranges or far inland where cyclone storms are weak and infrequent. The former is the case in North and South America, the latter in Eurasia east of the Black Sea. These dry intermediate climates may be divided into two main types: the semiarid, or steppe, and the arid, or desert type.

The middle latitude steppes and deserts generally have greater annual range of temperature than the neighboring regions of humid climates: summers are hotter and winters colder. The diurnal range also is relatively great: the days are warmer and nights colder than in the humid regions, and the passing of occasional lows may bring sudden and violent changes in temperature.

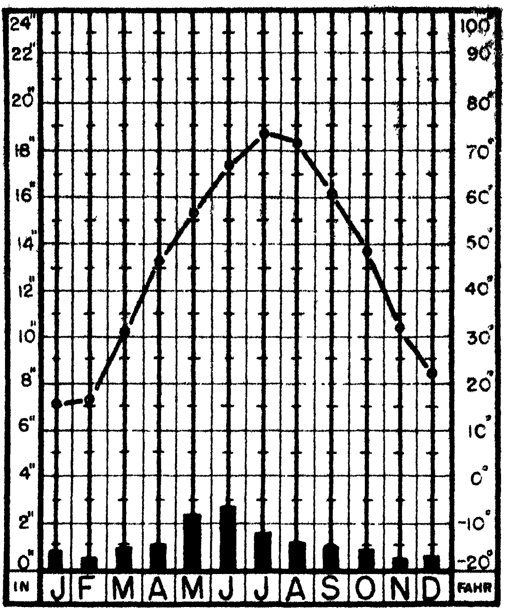
In general, the average annual rainfall in the semiarid intermediate regions is below 20 inches, and that of the deserts is less than 10 inches. Inasmuch as average annual temperatures are considerably lower than in the dry tropical regions, evaporation is less rapid and whatever precipitation falls is more effective. Therefore, less rainfall is required to make a climate humid than is true in the hotter areas.

Although in the semiarid lands trees are generally lacking except along the larger watercourses, the rainfall is sufficient to maintain a fairly continuous vegetative cover consisting of short grass and xerophytic bush, which can support grazing. Where rainfall is greatest, some of the land can be used successfully for crop agriculture. None of the deserts, except the Takla Makan of Chinese Turkestan, exhibits conditions of such extreme aridity as are found in the Atacama or in parts of the Sahara. However, vegetation is so sparse that the land can be used only for extensive forms of nomadic pastoral pursuits.

The Intermediate Semiarid Type of Climate

The most extensive semiarid regions in North America (Illus. p. 200, No. 12) are: (1) the Columbia plateau, lying between the northern Rockies and the Cascades, and (2) the Great Plains, extending from southern Texas well into Canada along the eastern front of the Rocky Mountains. Still more extensive are the steppes that extend from southern Russia far into the interior of Asia. The corresponding region of steppes in the Southern Hemisphere lies along the eastern base of the Andes in Argentina and in southeastern Australia (see World Map of Climatic Regions).

Temperature. Temperature conditions vary widely with latitude and altitude. The average summer temperatures, June to August inclusive, vary from 80°F. in Texas to 60°F. in southern Canada, while the winter temperatures, December to February inclusive, vary from 50°F. in Texas to 10° or 15°F. in southern Canada. The average length of the frost-free season is not less than eight months in the warmest portions, while in the colder areas it is but three to four months (Illus. below).



Middle latitude steppe climate. Average temperature and precipitation, Miles City, Montana Total precipitation 13.5 inches.

Winds. Although these semiarid regions lie in the belt of the prevailing westerlies, local weather conditions vary widely. In North America the westerlies bring moderate rainfall to the Columbia Plateau during the winter season, but east of the Rocky Mountains they produce little precipitation until after they have crossed the Great Plains. In late spring and early summer, when the storm paths are farther north than in winter, humid marine tropical air masses from the Gulf of Mexico may penetrate far inland and bring to the Great Plains the major share of their annual rainfall, partly in the form of thunderstorm precipitation.

In southern Russia and Siberia, cold northeasterly winds from the Asiatic high-pressure area prevail in winter, while during the summer the winds generally are from a northwesterly direction. During both seasons the effects of cyclonic storms passing to the northwest are occasionally felt. In the steppes of Mongolia the influence of the Asiatic monsoons predominates.

Wind velocities are relatively high across the unobstructed surfaces of most semiarid plains. In the northern Great Plains of the United States and Canada blizzards occur during the winter season: strong, cold winds accompanied by very fine, blinding snow. Severe blizzards cause heavy losses of domestic livestock and wild animals. During the summer season, on the other hand, hot winds are not uncommon, particularly in the lower latitudes along the eastern margin of the Great Plains. Protracted periods of drought and high temperatures cause such winds to be destructive to farm crops, and in some cases to the natural vegetation as well.

Humidity and rainfall. Although the average annual precipitation of most semiarid climates varies from about 10 to 20 inches, these limits are by no means exact. In the middle latitudes the semiarid regions of both the Americas have a wide extent north and south. Hence, differences in temperature, length of the growing season, and rate of evaporation, as well as rainfall, affect the degree of aridity. In southwestern Texas, for example, evaporation during the long warm season is about twice as great as in the shorter, cooler warm season of the northern part of the Great Plains. Consequently, areas in Texas with more than 20 inches of rainfall may be semiarid whereas those in the north may be classed as humid with even less than 20 inches.

In North America, crops of the cooler areas, in addition to being favored by a lower rate of evaporation, have the advantage of a highly favorable seasonal distribution of rainfall. This is particularly true of the Great Plains. At Calgary, Canada, 73 per cent of the annual rainfall occurs during the months May to September. On the Columbia Plateau 50 per cent of the annual rainfall may be expected from November to February, inclusive. The former climate strongly favors spring wheat; the latter, winter wheat.

Variability of rainfall is perhaps the most critical climatic factor in semiarid regions. Some years may have 50 per cent or more above the normal, while others may drop as much below. Such variability is of much greater economic significance where the average is near the lower limit of tolerance for crop plants than where the average is relatively high. There seems to be a tendency for comparatively wet and dry years to occur in groups, but without any dependable regularity. Furthermore, in the Great Plains particularly, rainfall is below the statistical average in more than half the years. In the same place the rainfall may range from a sufficiency to maintain humid agriculture to an amount hardly able to support scattered bush vegetation. This variability should be considered normal for most of the semiarid lands of the world. Agricultural and pastoral activities should be planned and practiced accordingly. During wet years preparation should be made for the drier years that will follow. There is no evidence at hand to indicate that any permanent climatic changes are now occurring.

Native vegetation. Regions of semiarid climates are characterized by comparative sparseness of vegetation, but the cover is practically continuous and thus contrasts with deserts, where it is patchy or entirely absent. There are four major groups of native flora, all of them of the low-growing type; trees are found only along watercourses. (1) In the more humid sections where the rainfall is sufficient to cause relatively deep penetration of moisture, grasses of medium height abound. This type of vegetation is transitional between the subhumid and the semiarid climatic areas, and thus is found within both. In the Great Plains of the United States, the semi-tall-grass vegetation occurs in both the eastern and northern portions, in the former because of a somewhat greater rainfall total, and in the latter because of the greater efficiency of the precipitation, which results from a lower evaporation rate. (2) The semi-tall-grass vegetation of the United States and Canada merges westward, and in Russia southward, into the short-grass type which to many is the typical steppe (Illus. below). (3) Where the rainfall is too low to support much grass, and where temperatures are relatively cool, sagebrush is likely to predominate. This type of natural vegetation prevails in the drier sections of Montana and Wyoming as well as on the Columbia Plateau, where it is dominant over large areas (Illus. p. 219). (4) In the southern part of the Great Plains, in New Mexico and southern Texas, mesquite and thorny bush interspersed with some grassy areas are the major phases of the vegetative cover.

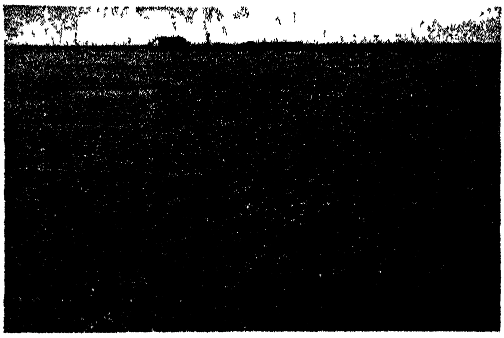


Photo by F J Weaver University of Nebraska

Short grass steppe of eastern Colorado

Soils. The mature soils of semiarid regions are pedocals. They are dark in color and have a zone of alkaline salt accumulation usually, although not exclusively, of lime carbonate. The color is generally dark brown in the more humid sections and lighter brown where rainfall is lower. Furthermore, they are darker colored in the cooler portions than they are in warmer areas.

The soils of the eastern Great Plains of North America are black soils, located in the transition belt from humid to semiarid climatic conditions. They correspond to the chernozems which developed under similar climatic conditions in the steppes of European and Asiatic Russia. They are darker than the true semiarid soils, and the zone of lime accumulation occurs at greater depths, usually from two to three feet below the surface.[*] The dark-colored horizon is 10 to 24 inches thick and has a stable granular structure. The black soils are among the aristocrats of soils, initially productive without the use of fertilizers, rich in humus, and readily tilled. Given a sufficiency of moisture, they will yield abundantly for many years. However, owing to the climatic conditions, long-range average crop yields on these soils are generally appreciably below those on the prairie soils and on many of the gray-brown podzolic soils. (Illus. p. 228.)

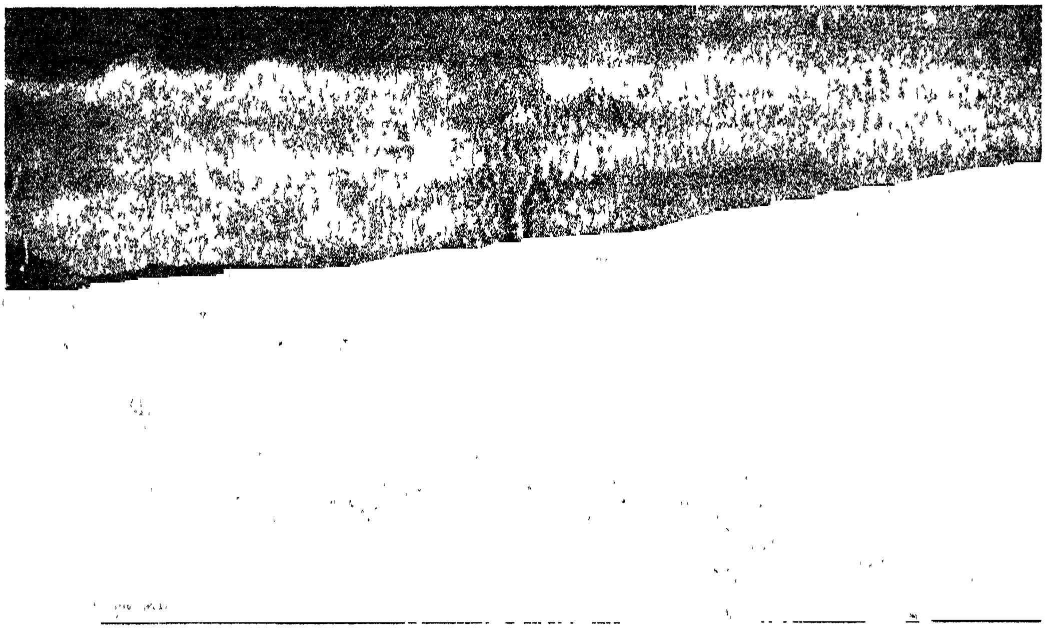


Photo by N A B

Sagebrush vegetation in western Great Plains. Irrigated valley, Dubois, Wyoming.

Where rainfall is less than in the chernozem areas, the soils are lighter in color and shallower, and the lime-accumulation zone is nearer the surface. On the basis of their color, these soils have been classified as chestnut and brown soils. They have been developed under a grass cover which, because of lower rainfall, was of lighter growth and had a shallower root system than the grasses which originally dominated in the black-soil areas. The lime accumulation zone occurs from six or eight inches to two feet below the surface.

In areas approaching desert conditions, where rainfall is too low to support continuous grass cover, the soils belong to a group known as the sierozems and gray desert soils. These are the principal soils in the Great Basin and Colorado Plateau regions of the United States. The color varies from light brownish gray in the north to almost reddish in the south. The surface horizon is a thin, pebbly layer, and under it is a zone of light, porous material. The subsoil is usually brown and compact. The zone of lime accumulation is near the surface and is often firmly cemented into a mineral hardpan. The gray desert soils are necessarily low in humus because of the paucity of vegetation which can be supported by the meager rainfall.

On the whole, the soils of the semiarid lands are readily tilled and are productive where water is available. Crops yield abundantly under irrigation, or without irrigation in years when rainfall is above normal. The unleached soils contain an abundance of soluble mineral salts. Since under natural conditions these salts are usually well disseminated throughout the soil, they do not impair productivity. However, when irrigation water is applied, care must be taken to provide adequate drainage or the alkali salts will become concentrated near the surface of the soil by the evaporation of excess moisture. Such concentration causes good lands to become "alkaline" and thus almost worthless for crop production. Costly errors involving disastrous consequences have been made in some of the irrigation projects by failure to recognize the danger of concentration of alkali salts.

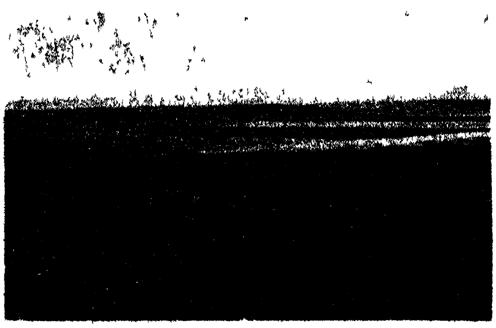


Photo by N. A. B.

Wheat farming in the short grass steppe of western Nebraska. Shows strips of fallow land alternating with strips of growing wheat.

Land utilization. Semiarid lands nearly everywhere mark the transition from crop farming to cattle along their humid margins and from cattle to sheep in their drier portions. During wet periods, crop farming may become so profitable that it encroaches seriously upon grazing lands, only to be forced to retreat again upon the inevitable return of dry years.

The semiarid regions are important in wheat production, autumn-sown varieties being dominant in the warmer sections and spring wheat in the areas where the winters are severe. The semiarid lands of Russia, Canada, and the United States include some of the greatest wheat-producing regions of the world. The wheatlands are located in the more humid portions of the steppe, where the accumulated winter moisture is augmented by sufficient spring and early summer rainfall to make a wheat crop before the heat and summer drought become severe. The best wheatlands are in the chernozem areas, where the sufficiency of moisture was early indicated by the taller grasses. Wheat is produced also in the drier areas of chestnut brown and brown soils, but yields are less dependable, and such lands are therefore more definitely marginal than are the chernozem districts (Illus. p. 228).

The wheat crops which ordinarily place Kansas, North Dakota, and Nebraska at the head of the procession in the United States are produced chiefly in the more humid portions of the Great Plains.

Cattle grazing is important in all semiarid regions, the intensity depending upon vegetation and marketing facilities. Forage crops are produced to supplement the natural pasture wherever pressure of population is such that the land can profitably be used to nearly its full capacity. Drought-tolerant forage crops, such as millets and sorghums, have been brought from Eurasia and introduced into the Great Plains with conspicuous success. The open range which formerly characterized the semiarid lands of the United States has given place generally to fenced ranches wherein pasturage of the native grasses is controlled more or less efficiently and is supplemented by fodder crops and, in some cases, by yard feeding. This change has nearly eliminated the cowboy as the picturesque character of earlier days. The "cow country" has been pushed into the drier regions of the southwest and but few of its original characteristics are now found within the Great Plains. In Argentina the cowboy, called the *gaucho,* is still a picturesque figure, but even there he is gradually being shoved westward and southward by the encroachment of crop farming and fenced ranching. It seems certain that in Argentina, as in the United States, the activities of the cowboy will be confined to lands where rainfall will not support grain production but where it is sufficient to maintain a grass cover.

Sheep ranching predominates in the drier sections where low rainfall, high evaporation, or poor moisture retentiveness of the soil result in sparse vegetation inadequate for cattle. It is an industry that may be considered transitional between the semiarid and the arid lands (Illus. below). Under poorer conditions some profits may still be made with goats. The livestock situation may thus be summarized by stating that the fat grazing lands are used for cattle, the sparse grazing lands for sheep, and the worst grazing lands, characterized by bush and hardy shrub, for goats.

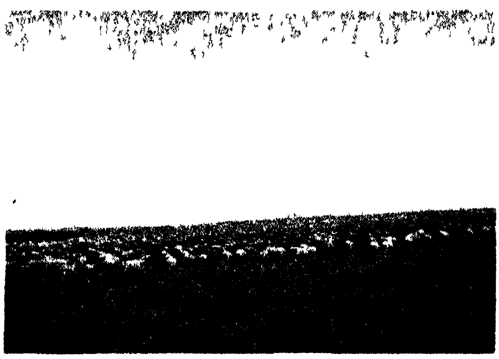


Photo by N A B

Sheep grazing on the short grass steppe, the Pierre plains near Ardmore, South Dakota.

Where water is available and markets are accessible, extensive irrigation systems have been constructed, particularly in the United States, east of the Rockies, from Montana to New Mexico. The greatest degree of success has been achieved in the northern half of the Great Plains, because of the larger size of the rivers which head in the mountains and flow across that section. Similar projects have been developed on the Columbia Plateau. High yields per acre may readily be obtained under irrigation, because generally the soils of semiarid regions are exceptionally fertile and the alluvial lands are easily tilled. The crops which have proved most successful belong to one of two types, either those which need abundant moisture with much sunshine and give large cash returns per acre, or those for which local demands are comparatively strong. Sugar beets, melons, specialized fruits, and early season vegetables are examples of the former, while feed and forage to supply the local grazing industry illustrate the latter. Since the areas under irrigation are small in comparison with the unirrigated uplands, the needs of the ranches for feeds to supplement the ranges, especially in winter, result in comparatively high prices for the forage and grain crops produced in the irrigated valleys. Furthermore, the ranchers of the Great Plains find it advantageous to finish beef cattle for the market, so far as possible, prior to sale, and for such purposes quantities of alfalfa, sorghums, and grains are demanded.

The production of specialized crops such as sugar beets, plus the production of feed crops for local markets, has given great impetus to the development of irrigation projects in the semiarid regions of the United States. This development has not been equaled in any other semiarid area of the middle latitudes. The belief that the national welfare of the entire country would be enhanced by making the slightly productive areas more productive, and thus adding to the national income and to national strength, has been an important factor in promoting this development.

The outlook. No climatic regions demand more careful study of the question "To what purposes should the land be put?" than do those of the semiarid type. Sound policies of land utilization must be based upon a knowledge and consideration of many factors. The topographic features, quality of the soil, native vegetation, length of growing season, severity of winters, heat of summers, the amount, seasonal distribution, and annual variability of rainfall—all are factors of major importance.

Economic returns from these regions depend upon the selection of such crops as are adapted to the existing natural conditions. For cultivated crops, methods of tillage to conserve moisture must be employed. The ability of the soil to withstand wind action and the erosive effect of dashing rains should be carefully studied before the native vegetation is disturbed. The economic factors should be given careful consideration. Crop production should be favored only where profitable returns may be reasonably certain on a basis of average or even below-average conditions, and should be discouraged in all sections where such returns can be expected only under the most favorable weather and market conditions. Large areas of semiarid lands still await exploitation in Asia, South America, and Canada, as do also smaller areas in the United States.

It is to be hoped that the mistakes of the past, wherein, during wet years, lands were broken and put into tillage regardless of soil conditions, may not be repeated. When several wet years follow one another in succession, as they may be expected to do, let owners and users beware lest they extend the cultivated acreage into areas where only grass can be permanently successful. Grass is nature's adaptation of arid land to the climate. Man should study carefully all the factors and the probable results before he destroys the sod.

The Intermediate Arid Type of Climate

The deserts of the middle latitudes, as a class, are not so completely desolate as are those of the low latitudes. In the latter, temperatures are high throughout the year, humidity is low, and the intensity of evaporation is great, whereas in the middle latitudes evaporation takes place slowly during the several months of the cold season. Furthermore, the average annual rainfall is slightly greater in most of the middle latitude deserts than in those of the low latitudes. As a result of the somewhat larger amount of rainfall and its greater efficiency in providing soil moisture, the scattered xerophytic vegetation is more abundant in the cool than in the warm deserts.

The best-known middle latitude deserts are in southwestern United States and central Asia. (See World Map of Climatic Regions.) The deserts of the Great Basin and the Mojave of California are examples of the former, and Takla Makan and Gobi of the latter. All are interior basins practically surrounded by mountains which prevent the inflow of vapor-laden winds.

Climatic conditions. The climatic conditions may be summarized in a few broad general statements. The average annual rainfall is less than 10 inches in most places, although in cooler areas desert conditions may not be reached until precipitation falls below 6 inches. Diurnal and seasonal ranges of temperature are pronounced; the maximum in summer is comparatively high and the minimum of winter is low. In summer, days may be hot and nights cool. Winds are strong and irregular. Freezing temperatures at night persist later in the spring and begin earlier in the fall than is generally the case in humid climates of the same latitude and altitude. Since, however, deficiency of rainfall is the one dominating cause of low productivity of the land, the other factors are of little significance.

Desert soils are generally gray, coarse, and stony. Sharp changes of temperature cause disintegration of the rock by mechanical processes, which results in the formation of relatively coarse materials. Chemical processes are retarded by coolness and dryness, and decomposition therefore proceeds but slowly. Because of low rainfall there is little leaching, and since much of

Courtesy Soil Conservation Service.

Subtropical semi-desert vegetation in Arizona. The tall cacti are *Saguaro*. A *cholla cactus* and a *barrel cactus* appear in the foreground. The low trees are *palo verde*. Note wide spacing of brush. Vegetation of this general character is a near approach to the desert. The lower forms correspond to the *garigue* of Italy, and the taller shrubs to the *maquis*.

the soak-in returns to the air by surface evaporation, the dissolved mineral salts are not carried away but are left in the upper part of the soil. Desert soils are rich in soluble alkali minerals, sometimes so rich that plant growth is impossible; but they are low in humus because of the scantiness of the vegetative covering.

Vegetation. Woody brush with thorns and hairy or resinous leaves typifies the plant life of the desert. Where winters are severe, herbaceous and fleshy plants die down, in contrast to warm deserts, where perennial cacti often grow to tree size and in some places into forest denseness (Illus. p. 224).

Land utilization. Middle latitude deserts are grazing grounds of extremely low carrying capacity. Cattle can be grazed only where supplemental feed is provided by mountain pastures or by irrigated crops. Sheep ranching is the most widespread phase of land utilization in the arid lands. But even this industry depends in no small measure upon pasture lands in the adjacent mountains or upon supplemental forage produced under irrigation.

In arid lands of the middle latitudes, as in those of the low latitudes where other forms of livestock fail, the goat may thrive (Illus. below). While in the New World the pressure upon the land has not forced maximum utilization of desert wastes to the extent that it has in the Old World, and therefore the goat has not become so common, goat raising is an industry of considerable importance in southwestern Texas, New Mexico, and some other areas of near-desert conditions. The goat is the last word in land utilization; where the land is too rugged or dry for goats, man can hardly expect to succeed with other forms of livestock. When pressure upon the land becomes much greater than at present in America, we may expect economic conditions to make goat raising in the desert wastes of the Southwest increasingly profitable.

Courtesy American Museum of Natural History. Photo by Roy Chapman Andrews

A herd of goats near the edge of the Mongolian desert

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Chapter Fourteen

PRINCIPAL AGRICULTURAL PRODUCTS OF THE INTERMEDIATE REGIONS

AGRICULTURE OUTSIDE THE TROPICS, and particularly in the regions of intermediate climates, is essentially dissimilar from that in the tropics. Its methods are different, it produces different crops, and it must meet different problems.

In the tropics subsistence agriculture prevails; commercial agriculture is carried on chiefly in the form of large-scale capitalistic enterprises under western management, though native commercial agriculture is increasing in importance. In the intermediate regions, though many farmers still produce primarily for their own immediate needs, commercial production is much more important but is generally carried on as relatively small-scale individual enterprises.

In the tropics the land can produce throughout the year, but in most regions outside the tropics, a cold season limits production. Shorter growing seasons and lower average temperatures make it necessary to grow hardier crops than those raised in the tropics. Thus there is, on the whole, little overlapping in the types of crops produced by the two major agricultural zones of the world, the tropics and the middle latitudes. Where the former grow rice, cassava, and sorghums as the major foodstuffs, the latter produce wheat, rye, and potatoes. Corn is one of the few crops common to the tropics, subtropics, and intermediate climates.

The animal industries, of secondary importance in most regions of warm climates, play a vital role in the intermediate regions, producing enormous quantities of raw materials, notably leather and wool, for industry, and meat, fats, and milk for food. The tropics produce little animal fats but much vegetable fats, some of which are indispensable to modern industry. Relatively few products are common to both the tropics and the middle latitudes, the principal ones being sugar and tobacco. Although tropical sugar does compete with sugar produced from beets, and could do so even more successfully if no tariff restrictions existed, many of the tropical tobaccos, because of their unique aroma, really should not be considered competitive with those raised in the intermediate climates. Tropical fruits likewise are largely noncompetitive because they differ so materially from those grown elsewhere. Thus, the products of tropical and middle latitude agriculture are so diverse that they give rise to an extensive commercial interchange, a trade necessary to the welfare of the people of both of these climatic zones, and one which should increase in volume so as to raise the standard of living of all.

Among the numerous nonindustrial products of the middle latitudes, only those are discussed here which are of great importance from a world point of view and which enter international trade in relatively large quantities. In the regions of intermediate climates, production of fruits and vegetables on a commercial scale considerably exceeds similar production in the tropics and subtropics; but in comparison with the other products of agriculture, their importance is so small that they are not included in the following discussion.

Wheat

The most important food of the inhabitants of the middle latitudes and dry subtropical regions is and long has been some form of bread. Archeologists, searching for remains of human occupation and human life in the ages that preceded the period for which we possess definite historical records, have often found caches of grain, and sometimes even evidence of breadmaking. In the book of "Genesis" man is ordered to earn his own bread, and the principal prayer of Christianity includes a reference to this all-important staple food.

Wheat is the best breadmaking grain, and thus, wherever man has settled in the intermediate and dry subtropical regions, he has planted it. From ancient times it has been a staple crop on which not only the life of individuals but often even the stability of states has depended.

Climatic adaptability of wheat. The wide geographic distribution of wheat, from central India to southern Finland and from Central America to the Peace River, was made possible by its adaptability to various climates. This adaptability is largely a result of the fact that botanically the genus wheat (*Triticum*) consists of several species, most of which have developed numerous varieties, adapted to various sets of environmental conditions.[1]

Notwithstanding its great adaptability, wheat cannot be grown in some extensive areas because of adverse climatic conditions. Where winters are long and severe and summers cool, with growing seasons of less than a hundred days, little wheat is produced. It is virtually absent in the regions with a subpolar type of climate; in North America and Eurasia these regions approximate the broad belt of northern coniferous forests (see World Map of Climatic Regions).

Equatorward the limiting factor is essentially a combination of temperature and humidity. It is not altogether impossible to grow wheat under tropical conditions, but the plant becomes so susceptible to diseases that such a possibility is only of academic interest. Practically speaking, wheat is not produced in regions of humid tropical climates. The warm limits, however, vary considerably from place to place. In humid subtropical regions, as in southern China and southern United States, wheat is of little importance. In the dry subtropical regions, however, wheat is the principal grain. There it is sown during the late fall and early winter. It matures during the late spring and is harvested in the early part of the dry summer. Under such favorable climatic conditions wheat is grown in rather low latitudes in French North Africa, Egypt, and Palestine. On the dry western part of the Deccan Plateau of central India, where a tropical savanna climate prevails, the cultivation of wheat extends to within 15° of the equator. This, however, is an exceptional case; nowhere else within the tropics is wheat grown extensively, except at high altitudes, where the climate is not tropical.

The planting season—winter and spring wheats. The common distinction between spring and winter wheat refers primarily to the time of planting and does not necessarily indicate a difference in species. By slow adaptation spring wheats may be changed into winter types, and vice versa. A wheat which is fall-sown on the plains of northern India, where mild winters prevail, might have to be sown in the spring on the plains of Nebraska and Kansas, where the winters are rather severe. In some countries it is difficult to distinguish clearly between fall and spring varieties. In northern Africa the sowing season lasts well into January, while in southern Argentina it does not end until the first half of August, the equivalent of our northern February. If the winters are severe enough to kill a high percentage of the wheat plants, the sowing generally is done in the spring. This is the case where frosts come early and average winter temperatures are low.

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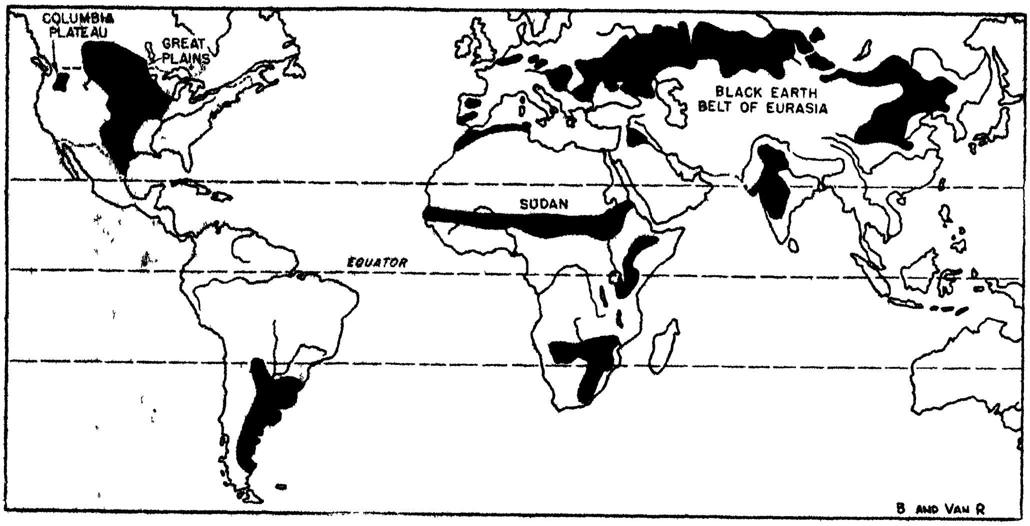
[1] Among the principal species of wheat should be mentioned common wheat (*Triticum vulgare*), club wheat (*T. compactum*), spelt wheat (*T. spelta*), durum wheat (*T. durum*), rivet or cone wheat (*T. turgidum*), Polish wheat (*T. polonicum*), and emmer (*T. dicoccum*).



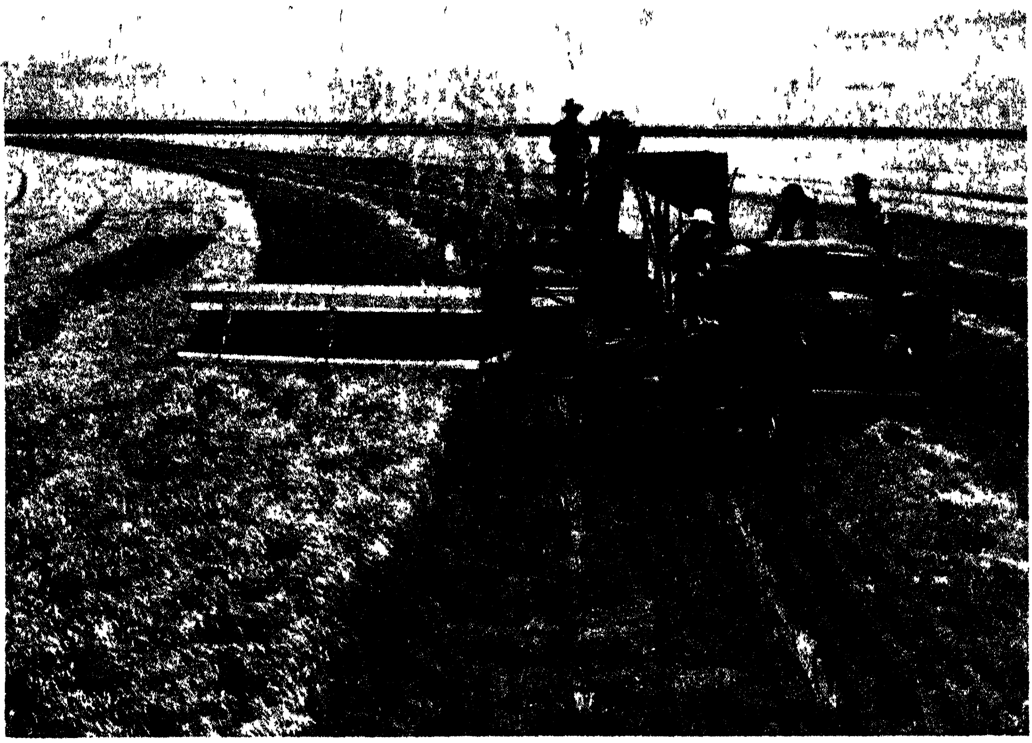
Principal black-soil and related soil areas of the world

Moisture requirements. The optimum precipitation for wheat seems to lie somewhere around 32 inches per year, varying, of course, with seasonal distribution and with temperatures. Where temperatures are relatively cool, excess of moisture has a decidedly unfavorable effect. Thus, little wheat is grown in the rainy coastal lands of Oregon, Washington, British Columbia, Ireland, and western England. On the other hand, it still does well where precipitation is considerably below the optimum, and under such conditions its yields are affected less than are those of most other crops.

Wheat as a subhumid and semiarid crop. As a result of this ability to grow where most other grains do not give satisfactory yields because of lack of moisture, the cultivation of wheat has in many parts of the world been pushed into subhumid and even semiarid lands. An additional reason is that, under conditions of low rainfall, high-protein wheats are produced, eminently suitable for breadmaking, and which therefore command a higher price than do the softer wheats of the more humid regions. In the latter regions, also, a higher yielding and more profitable crop such as corn may tend to push out wheat economically.

The subhumid and semiarid lands of the middle latitudes had an original stand of grass. The scarcity of water and timber on these grasslands long formed obstacles to their agricultural utilization. The soils, black chernozems and related soils, are, however, very fertile, because the low rainfall prevents the loss of valuable plant salts through leaching and the age-long grass cover has enriched the soils with humus materials that impart the dark color (Illus. above).

Soil requirements. Wheat prefers fertile silt or clay loam soils, especially those which contain a certain amount of lime. On the stony, glacial soils of New England where corn gives satisfactory yields, wheat has never done well except during the first few years of cultivation. Although in this case climatic and soil factors are difficult to separate, the latter undoubtedly strongly affect yields. On the well-drained, fertile, marine clay silts of the Netherlands and northwestern Germany, wheat is successfully grown, but on the adjoining sandy and infertile glacial soils it cannot be economically raised even for local consumption.



Courtesy Soil Conservation Service

Harvesting of wheat with a 12-foot combine and row crop tractor on a terrace and contour farmed field near Clovis, New Mexico

Colonization of the temperate grasslands. In Russia, the settlement of the steppe proceeded slowly during the eighteenth and nineteenth centuries. Likewise, in other parts of the world the farmers, accustomed to an agriculture developed in forest regions, long regarded these grasslands as unfit for anything but the cattle industry. Extensive tillage agriculture did not become practical on the subhumid grasslands until the latter half of the nineteenth century. Then, with the aid of modern agricultural machinery and well-drilling equipment, and with the facilities offered by railroad transportation, extensive farming became profitable on large areas formerly deemed unfit for tillage (Illus. below). Wheat was the staple crop which gave the quickest returns on the initial expenses of colonization. Thus, within a brief period, the subhumid and semiarid lands outside the tropics became not only large producers of wheat, but also its chief exporters. As a repercussion to this revolutionary development in world agriculture, the acreage of wheat declined in western and southern Europe and in the United States east of Chicago. In western Europe this development caused the severe agricultural depression of the eighties and nineties.

In many countries government protection of the wheat industry has tended to retard this downward trend, or even to reverse it.

Principal wheat-producing regions. Even with the limitations imposed by climate, soil, and economic and social conditions, wheat is grown widely in the intermediate and subtropical regions for both subsistence and commercial purposes. Among the important producing countries are several in which large quantities are produced for the home markets and where the crop has only an indirect influence upon world trade and world prices. Among these should be mentioned the Soviet Union, France, Italy, India, China, Spain, and Germany. Because of their large populations, however, they consume practically all they produce, and in subnormal years they even import considerable quantities. The principal producers from a commercial point of view are Canada, Argentina, Australia, the United States, and the countries of southeastern Europe. Argentina and Australia, both of which play an important role in the world's wheat trade, rank below France and Italy in total output, but their sparseness of population and absence of important industrial districts enable them to export a large percentage of their crops.

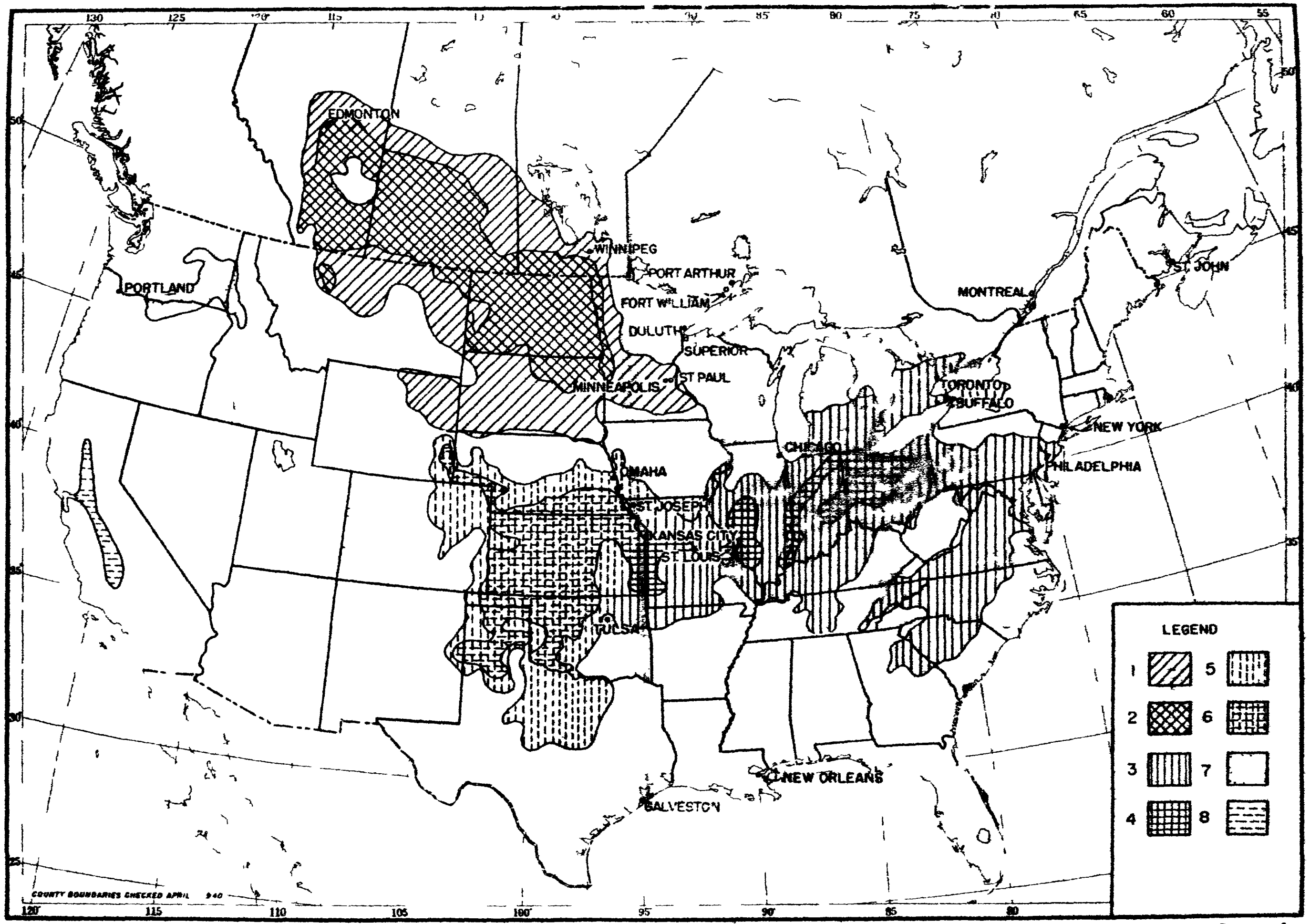
Wheat in North America—limits of wheat cultivation. The world's most important area of commercial wheat production lies in the Great Plains of North America, and extends from northern Texas to the Peace River district of Alberta (Illus. p. 238). It is limited on the north by the short and cool summers of the subpolar climate and on the south by the increasing heat and humidity of the subtropical climate of the Gulf Coast region. Eastward, cotton and corn replace wheat in the southern half of the United States because they give larger returns per acre. In the central United States and farther to the north, dairy farming reduces wheat to a subordinate position.

To the west, the percentage of the land in wheat gradually decreases with the increase in aridity. Along the entire western margin of the wheat belt lies a broad strip where wheat farming, and for that matter ordinary tillage agriculture in general, is decidedly uncertain. The fluctuations in rainfall from year to year make farming a hazardous enterprise. In some districts the precipitation of one year regularly falls below the minimum necessary to raise a crop, and the accumulated precipitation of two or more years is used for one crop by means of "dry farming" methods.

In this marginal zone the western limit of wheat production swings back and forth. During periods of comparatively heavy rainfall and high prices, agriculture tends to move westward. In dry years, and in periods of economic depression, agriculture retreats before the advance of the livestock rancher. This region is truly a "permanent pioneer belt."

In North America the wheats grown east of approximately the 95th meridian are predominantly of soft and starchy texture, while those of the less humid regions to the west of this line are, with the exceptions of those grown in the Pacific Coast states, hard and vitreous and generally of higher protein content. These bear the market classifications of soft and hard wheats, respectively. The hard-wheat belt of the Great Plains is the foremost producing region of North America.

THE HARD RED SPRING WHEAT REGION. The American hard-wheat belt can be divided into two sections, the northern and the southern, separated by a narrow gap in northeastern Nebraska where wheat is of little importance. The northern section, in Alberta, Saskatchewan, Manitoba, parts of Montana, North Dakota, South Dakota, and western Minnesota, occupies the larger area and is the greater producer of the two. Because of the long, cold winters, spring-sown varieties are grown almost exclusively; therefore the region is commonly referred to as the *hard red spring wheat region* (Illus. pp. 231, 238). The climate is subhumid to semiarid. The soils belong to the groups of the brown and chestnut brown soils, the chernozems, and prairie soils, all rich in



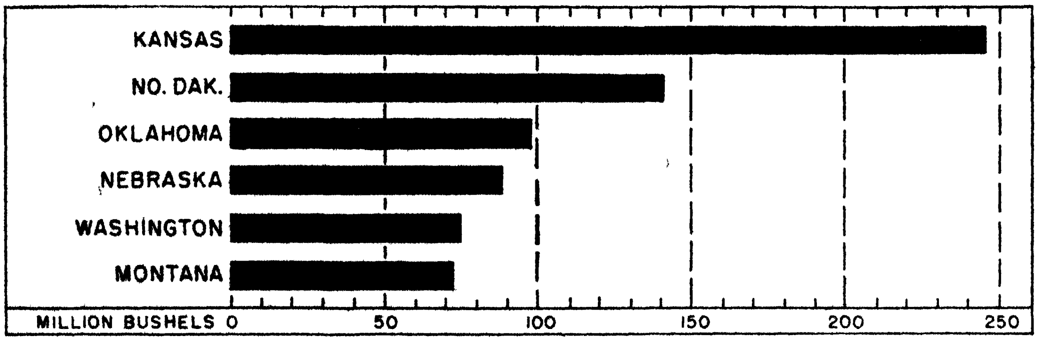
Courtesy Univ of Maryland, Dept of Geography

Wheat Regions of North America 1 Spring Wheat Region areas of less dense production 2 Same areas of dense production 3 Winter Wheat Region, humid portion areas of less dense production 4 Same areas of dense production 5 Same, sub-humid portion areas of less dense production 6 Same areas of dense production 7 Columbia Plateau Wheat Region 8 Valley of Caliplant foods. The wheat is of excellent quality, hard and with a high protein content. Considerable durum wheat is grown also in this region. Although durum is not well adapted for breadmaking, it is highly esteemed in the manufacture of such wheat products as macaroni and spaghetti.

Most of the Canadian and a large percentage of the United States spring wheat is exported via the Great Lakes waterway, through the Canadian ports of Fort William and Port Arthur and the American ports of Duluth and Superior. The principal export centers are Montreal, New York, Philadelphia, and Baltimore, the United States ports ranking foremost during the winter when the St. Lawrence is ice-bound. Much of the American spring wheat goes to various interior milling points, of which Minneapolis and Buffalo are the most important.

THE HARD RED WINTER WHEAT REGION. The southern section of the plains wheat belt embraces parts of Nebraska, Kansas, eastern Colorado, Oklahoma, and Texas, the state of Kansas ranking first by far in production (Illus. p. 231). This is the *hard red winter wheat region.* In this area the winters are so short and mild that the grain can be sown in the fall. The wheat is not quite so hard as that grown farther north, but it nevertheless is a highly desirable type for milling into bread flour. While much of this grain moves to interior primary markets and reshipping points, such as Kansas City, St. Joseph, Omaha, and St. Louis, more than a fourth of the crop in past years has been shipped to coastal points, especially Galveston and New Orleans, and exported from there. The hard red winter wheat region is normally the foremost source of wheat exports from the United States.

THE SOFT WINTER WHEAT REGION. To the east and south of a line running approximately from Tulsa, through Kansas City to Chicago, lies the *soft winter wheat region,* which reaches across the Appalachians to the Atlantic Coast in northern New Jersey, Delaware, Maryland, and northern Virginia. This area is bordered by the Corn Belt and the hay and dairying region on the north, in both of which regions wheat is important locally, and by the Cotton Belt on the south. The wheat grown is winter-sown, and rather soft, owing to greater humidity. On the whole it is not so well suited for bread flour as the harder varieties grown farther west, but it makes high quality pastry flour. Some soft white winter wheat is grown in southern Ontario and western New York. Although the eastern soft winter wheat region accounts for nearly a third of the total wheat acreage in the United States, most of it is consumed within the country and but little of it enters international trade.



Principal wheat-producing states of the United States. Average 1946-1948.

THE COLUMBIA PLATEAU REGION. Another important center of wheat production is located on the Columbia Plateau of Washington and Oregon and western Idaho. Various types are grown in this region. The winter climate is mild, and although both hard red winter and hard red spring wheats are grown, especially in drier locations, the softer varieties, such as white club wheat, dominate. Most of the crop is consumed in the western part of the United States, but large quantities are exported from Portland and neighboring Pacific ports to Europe and the Far East.

Canadian and United States exports. The United States can and usually does produce much more wheat than is needed to meet domestic demands. Wheat is a cash crop and is better adapted to the climatic conditions of a large part of the subhumid plains than is any other grain. Therefore, the wheat farmer has been greatly dependent upon foreign demands for the disposal of his surplus. In the years just before World War II competition on the world market had become increasingly difficult for the farmer, partly as a result of greatly increased production in the other exporting countries and partly as a result of the protectionist policies of many of the importing countries as well as those of the United States. Consequently, exports declined so that the United States ranked below Canada and Argentina, and often below Australia. After World War II, United States wheat exports increased greatly for a few years.

Canada ordinarily holds first rank in wheat exports among the countries of the world, chiefly because of the sparse population and the large areas of prairie lands suitable for the production of this crop.

Wheat in Argentina—climate and soils. The wheat region of South America is located in a huge semicircle around the estuary of the Rio Paraná, the Rio de la Plata. Because of its peculiar outline (Illus. p. 235) is often referred to as the "wheat crescent" of Argentina. In Uruguay wheat production is of small but increasing importance. The latitude of the "wheat crescent" corresponds to that of northern Texas, Oklahoma, and Kansas. Thus it may be compared with and actually is competitive with the hard red winter wheat region of the United States. As a result of the narrowness of the land mass of southern South America, continental influences are much less pronounced in the climate of the eastern Argentine than in corresponding parts of the United States. The winter temperatures are mild—only occasionally below the freezing point—and the summers are warm. The climate of part of the area is humid subtropical. Over much of the area, however, precipitation is lower than in other regions with a similar climate. It ranges from approximately 40 inches in the neighborhood of Buenos Aires to 20 inches near the western edge of the Pampa region proper. From here westward and southward it decreases rather rapidly to 10 inches and less. The soils of the "wheat crescent" are derived from loess and loesslike materials and bear strong resemblance to the fertile dark soils of the middle western part of the United States, although often slightly more leached.

Wheat farming as an adjunct to the cattle industry. The natural vegetation of this section of Argentina and the neighboring lands in Uruguay is grass—the *Pampa.* As in other grassland areas, livestock raising was once the only important agricultural activity, and to a large extent it still dominates the economic life of the country. In many districts the cultivation of wheat is carried on in close association with the cattle industry. Areas of land are leased by the owners for short periods to immigrant share tenants, the majority of whom are of southern European origin. At the end of the leasehold the tenant is required to leave the land in alfalfa, for which it has been prepared by the cultivation of wheat during several successive years. The tenant usually moves on to some other piece of land, where the same process is repeated. The harvest takes place during November, December, and early January; thus the wheat can be marketed when stocks in Europe, the principal center of consumption, are beginning to run low. Cheap land, cheap labor, good railroad facilities, and proximity to ports such as Buenos Aires, Rosario, and Bahía Blanca aid in keeping down the costs of transportation. Argentina, therefore, is an important factor in the world wheat market, ranking second only to Canada as an exporter. Large areas are still available for wheat, and if market conditions should warrant it, production could easily be doubled.

One of the main problems facing the Argentine wheat industry is that of transportation from farm to railroad. In a loess region, where stone is scarce, roads are expensive to build. Storage facilities also, especially in the country, are inadequate, resulting in a rush to market as soon as the crop is harvested. This practice sometimes depresses the price of the grain on the farm to unwarranted levels.

Wheat in Australia. In Australia wheat is the principal grain crop, occupying over half of the area of tilled land. It is grown chiefly in the regions of Mediterranean climate, the leading states being New South Wales, Victoria, South Australia, and Western Australia. The winter rainfall ranges from 10 to 20 inches; at other seasons the rainfall is slight. In many districts dry-farming practices are necessary to assure a crop (Illus. 235).

Seeding generally occurs in the fall—that is, in April and May—and harvesting is done in late spring and early summer, the beginning of the dry period. Australia, like Argentina, thus enjoys the commercial advantage of being able to market its crop early in the year. The principal handicaps of wheat growing in Australia are: (1) great distances from the European market centers, and (2) unreliability of rainfall, which leads to great fluctuations in production. While Australia ranks below France and Italy in total production, because of its small population it ordinarily consumes less than half of its crop, and so holds fourth or third place in export trade. Most of the wheat is shipped westward through the Suez Canal to Europe, but annually considerable quantities are exported in tramp sailing vessels via Cape Horn, giving rise to the so-called "grain race" to English ports. After World War I, however, the Far Eastern countries, especially Japan, became important as markets for Australian wheat.

Wheat production in Europe and elsewhere. Although much wheat is produced in western and southern Europe, particularly in France, Italy, Germany, and Spain, it all supplies domestic consumption. The principal European export centers lie in the Lower Danube Basin of Romania and Bulgaria and in the Hungarian Basin. Russia, the greatest European producer, no longer regularly has an export surplus (Illus. p. 235).

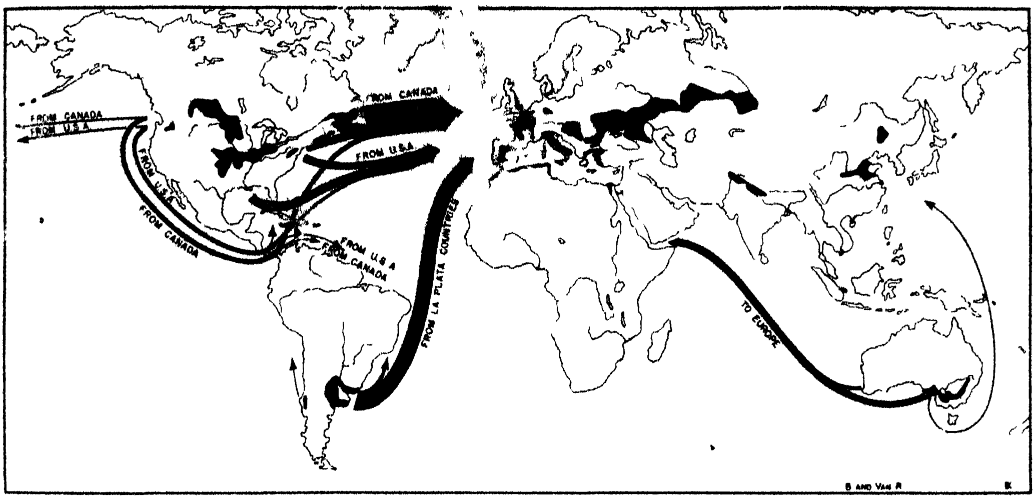
In all three of these eastern regions the climate is decidedly continental, with cold winters and hot summers. The seasonal distribution of rainfall, with spring and early summer maximum, is favorable for wheat production. The amount of annual rainfall decreases eastward. In the Hungarian Plain it ranges from 28 to 20 inches, in the wheat districts of Romania from 24 to less than 16 inches; still farther east, in the wheatland of the Soviet Union, it decreases eastward to an average of 12 inches in the lower Volga districts near Saratov. The natural vegetation over most of these areas was, and to a certain extent still is, grass; the soils generally are fertile, either chernozems or chestnut brown and brown steppe soils.

In the Danube plains and in southernmost Russia, winter wheats predominate. In most of Russia, however, the snow cover is too light to protect the plants from the effects of the severe winters, and therefore spring-sown varieties must be grown. In much of southern Russia the wheat industry is subject to the same handicaps as in the Great Plains of the United States. Winter snows and spring and early summer rains fluctuate greatly in amount from year to year and deficiency of moisture often causes crop losses and sometimes famine conditions. It is in this part of the world that "dry farming" was first practiced.

The belts of black, chestnut, and brown soils on which most of the wheat of European Russia is grown extend across the Ural

Mountains into Siberia. They gradually become narrower, and east of the Yenisei River they break up into isolated areas which continue to the brown and black soils of Mongolia and the Manchurian Plain. Wheat cultivation has followed this belt far eastward into Siberia (Illus. p. 228).

The quality of wheat improves from west to east with increasing aridity. The wheats of the Hungarian Basin and the lower Danube area are comparable with the hard red winter wheats of the United States, and some of the Russian wheats can be compared with the best hard spring wheats produced in Canada and northern United States.



Principal wheat producing regions of the world and wheat trade. Based upon 1922-1923 to 1928-1929 average and adapted from Holbrook Working and P S. King, "Graphic Representation of Wheat Trade," Wheat Studies of the Food Research Institute, Vol 6, No. 10, 1930.

Among the other wheat-producing areas of the world should be mentioned northwestern India, northern China, northern Africa, especially Algeria, and Manchuria. The commercial importance of these areas is, however, relatively small.

Wheat yields. Yields of wheat differ greatly in accordance with cultural methods and climate. In the great semiarid areas that produce the principal surpluses in the United States, Canada, Argentina, and Australia, farming is mechanized and extensive and yields of wheat average only 12 to 14 bushels per acre. In the Soviet Union, early in the Five Year Plans, only 10 bushels per acre were obtained. At the opposite extreme is the intensive rotation agriculture of humid northwestern Europe, where wheat is raised on a small scale as part of a rotation with hay and root crops and in connection with livestock that provide manure for fertilizing. Here Belgium, the Netherlands, and Denmark have regular yields of 40 to 45 bushels per acre. In France, Italy, and Hungary yields are about 22 bushels per acre under normal conditions; in China, Turkey, and Romania, 15, and in India about 11.

Wheat as a commodity of international trade. Wheat not only keeps well during storage and transportation but it is in great demand as a basic foodstuff in many parts of the world, especially in the middle latitudes. Although in some countries, as in the United States, the per capita consumption has contracted slightly as a result of changes in the diet, in other countries, as in Japan, the demand has been growing. Good bread flour requires a considerable amount of careful blending. For these reasons wheat has become one of the principal articles of the world trade in raw products, and the trade in flour likewise is highly important. The United States is the leading exporter of flour.

The principal centers of consumption and deficit production are western Europe and eastern United States. Both areas are densely populated and highly industrialized; furthermore, climatically they are better adapted to other crops than wheat. Of the two, Europe is the more important consumer. Large quantities of wheat are shipped there each year from Canada, Argentina, Australia, and the United States (Illus. p. 235). The Danube plains likewise find important export markets in western and southern Europe. In recent decades the demand for wheat in Japan and China has increased materially, resulting in increased shipments from Canada, the United States, and Australia.

Rye

As a bread grain, rye is much less satisfactory than wheat. Rye bread is dark brown, compact, and usually soggy inside. It is generally referred to as "black bread." In Europe rye bread is eaten chiefly by the poorer classes. Because of its poor quality and the social stigma attached to its use, a popular prejudice against it has developed. Wherever people can afford to do so, they eat wheat bread, or rye bread with a considerable admixture of wheat flour.

The importance of rye as a bread grain is slowly declining. Nevertheless, it still is a major food in countries such as Russia, Poland, Germany, and Czechoslovakia. In Russia the rye acreage closely approximates that of wheat, and the total quantity of rye produced often exceeds that of wheat. Although on the whole rye has decreased in importance as a breadstuff, it has increased in importance as a feed crop, and therefore the world acreage has tended to remain about stationary.

Rye as a crop of poor soils. Where soils are leached, acid, and too poor for wheat, and where the climate is too raw, rye is a grain that may still give a satisfactory yield. It needs less heat and can stand more moisture. Winter rye survives where most of the winter wheat would be frost-killed. Rye is autumn-sown in most places, but both as a winter and a spring grain it reaches much farther north than wheat.

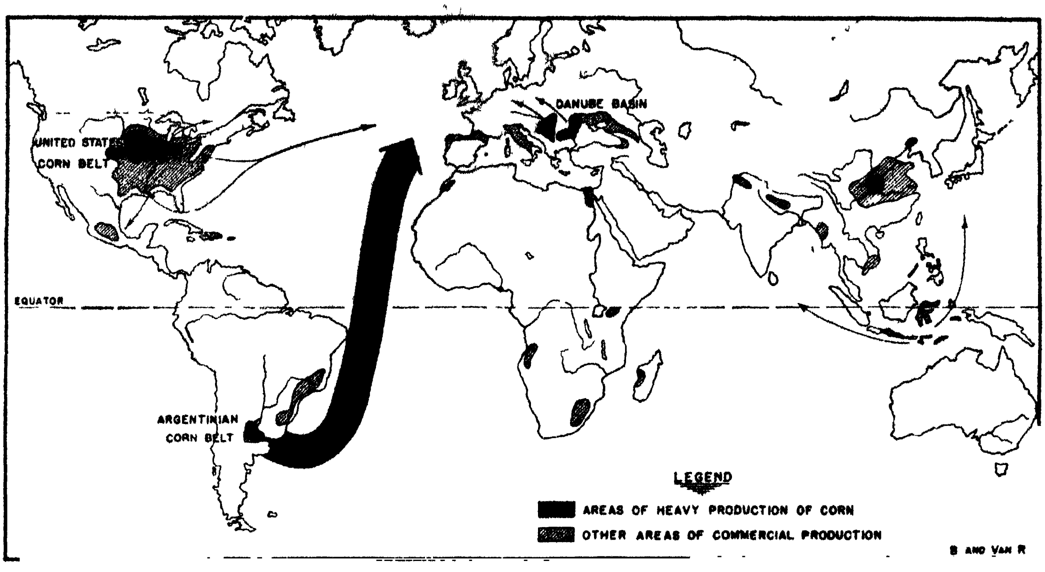
While it is grown to some extent on fairly good soils, rye is the typical grain of the poor, leached podzols which have developed upon the sandy glacial mantle rock and under the cool, moist climatic conditions in continental Europe north of the fiftieth parallel. Farther south rye occurs locally in areas of poor soil, unfavorable climate, or both, as on the Central Plateau of France, in Brittany, and on some of the sandier soils of the Hungarian Plain. Little rye is grown outside of Europe. In the United States the total rye acreage is small; the chief centers are in areas of comparatively poor soil and cool climate in North Dakota, Minnesota, South Dakota, and central Wisconsin.

In comparison with wheat, the world trade in rye is of little importance. The principal exporting countries are the Soviet Union, Poland, Hungary, and Argentina.

Corn

Although corn was not known to Old World agriculture until after the discovery of America, it is now one of the world's most widely produced cereals. It is grown in every country in the New World from Canada to Argentina. Its numerous varieties are adapted to many climatic conditions: it can be produced where little rain falls, as in southwestern United States, or where rainfall is abundant, as in New England. It is grown on a commercial scale where the growing season is only 90 to 100 days long, and where it is twice or thrice that length. It is also tolerant of different topographic locations, its cultivation ranging from the low-lying coastal plains of eastern United States to steep mountain slopes of Colombia and Peru, where it thrives at altitudes exceeding 8,000 feet.

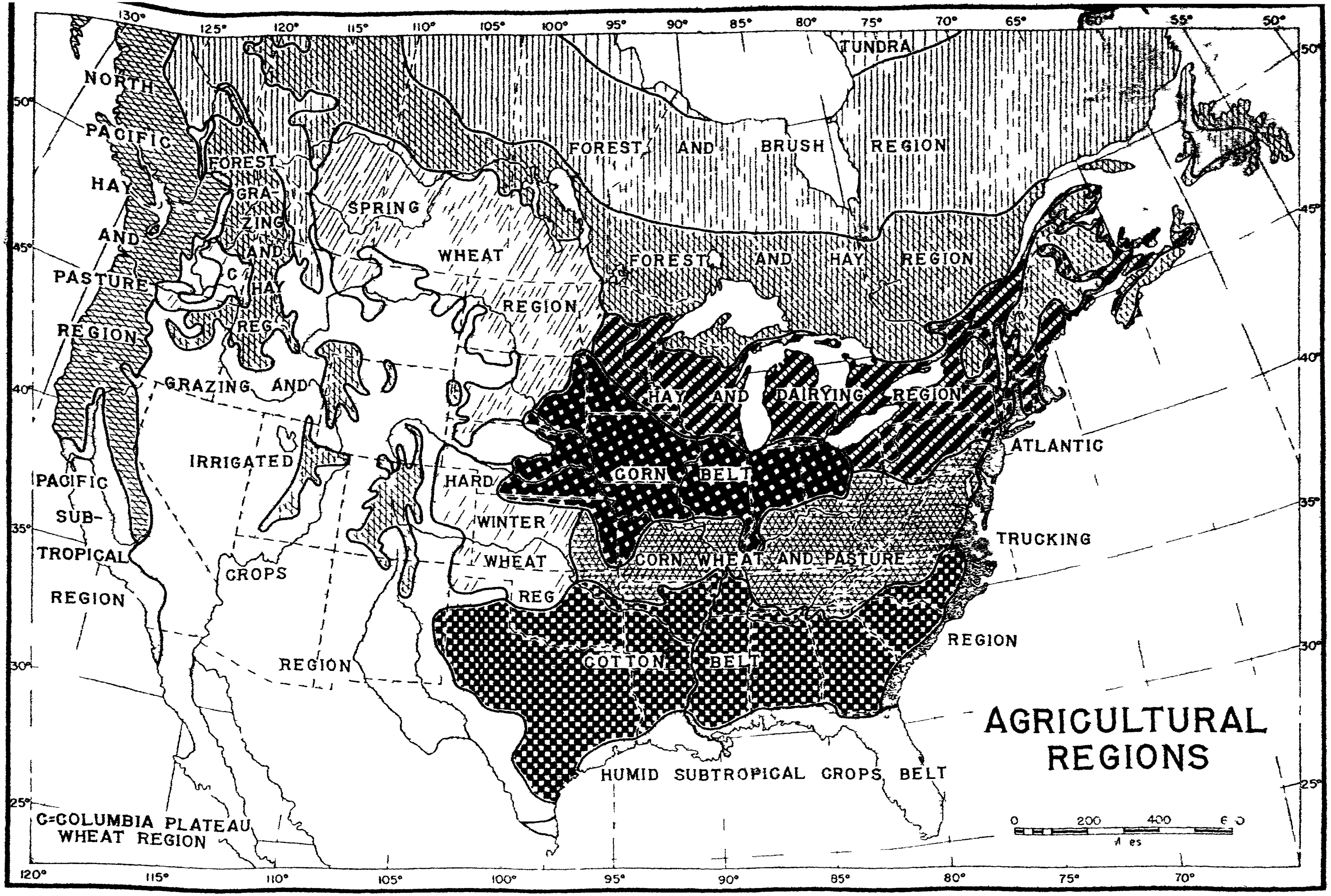
It is used as a breadstuff by millions of people scattered over the warm lands of the earth. It is used as a feedstuff for domestic animals in many of the middle-latitude countries, and thus is a splendid raw material out of which swine and steers make choice pork chops and tender steaks. Numerous prepared foods are made from corn, such as grits, hominy, cornflakes, corn syrup, and corn oil. Industrial products by the dozen are or can be made from corn or corn stalks: for example, starch, alcohol, paper, rayon, and fiber boards. Corn cobs are extensively used as domestic fuel. However, the sales of corn for commercial processing in this country amount to only about 7 per cent of the entire production.



Principal commercial corn producing regions and international trade in corn.

Importance of corn to American colonists. Maize was the staple cereal food of the Indians. It soon became a staple cereal in the English settlements of Jamestown and Plymouth. Under pioneer conditions it had distinct advantages over the imported European rye, oats, and wheat. For these small grains, fields needed to be plowed, and this required complete clearing of the dense forests. At first such clearing was impossible, but corn did not require plowed land. Girdling trees with an axe was a simple process, and standing dead trees were but little hindrance to corn culture. The corn was planted by hand in "hills." The separate hills could be fertilized with fish. Cultivation required only a simple hand hoe, and the harvest was a leisurely process of gathering the ears when time and circumstances proved convenient. Storage on the ear was relatively easy. No wonder corn became recognized as a life saver by the colonists, and that its introduction into our agriculture is considered a hallowed event in American history.

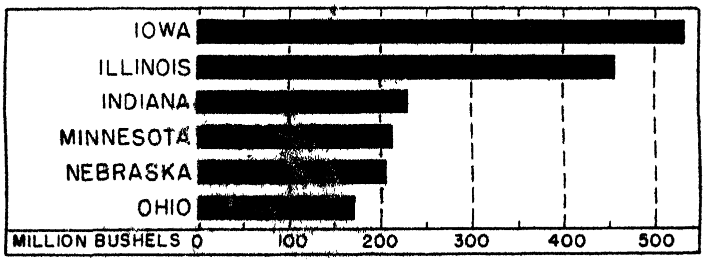
Westward expansion of corn production in the United States. The factors that made corn profitable to the colonial pioneers made it highly useful under similar conditions farther westward. With the pioneers, corn production moved westward slowly over the hilly, forested lands. The advancing wave of farmers depended upon corn to furnish food for man and feed for the animals while new lands were being cleared, settlements extended, and transportation facilities provided. During all this time of slow advance over woodlands to be cleared for farming, corn was important as a subsistence crop rather than as a cash crop.



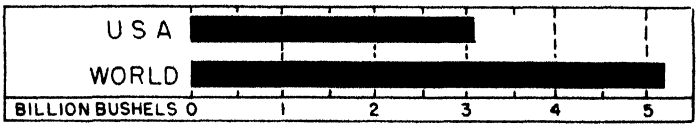
Courtesy Univ. of Maryland, Dept of Geography

Agricultural regions of North America

With the opening up of the prairie lands the picture changed; grasslands needed no clearing because they generally were treeless and free from boulders. The soil was rich and the summer rainfall ample for the heavy demands of growing corn. Large fields and surplus production resulted, quite in contrast to the small fields and local subsistence crops of pioneer days in the eastern woodlands. As previously pointed out (page 229), the period 1830-1880 marked the conversion of the humid grasslands of the Mississippi Valley from an area of grazing to one of grain farming. These lands, together with adjacent cleared forest lands, then became and have since remained the great Corn Belt of the United States.



(A) Average production, 1946-1948, of six leading corn states.



(B) Average yearly production of corn, 1944-1946, inclusive.

The American Corn Belt. The Corn Belt extends from central Ohio to central Nebraska, a distance of nearly 900 miles. Its width, north and south, varies from about 150 to more than 300 miles (Illus. p. 238). The states leading in total production are Iowa and Illinois, generally holding first and second places, respectively. Nebraska long held third place but has been surpassed by Indiana and Minnesota (Illus. A, above). Although corn is widely grown on every continent, nowhere else does such a large stretch of land possess nearly optimum conditions for its production, and the United States regularly produces at least half of the world's corn (Illus. B, below). The climatic factors include a growing season of 120 to 170 days, rainfall of 25 to 40 inches per year, and summer temperatures averaging above 70°F., with the midsummer period one of tropical warmth. Rainfall, mostly from thunderstorms, is heaviest during ~~the summer~~ months. It reaches its apex in July, is still heavy in August, and tapers off to a minimum in autumn and winter. The growing season is favored with a high percentage of sunshine, an important factor in promoting growth of the plant. The dry, cold winter facilitates storage at low cost with small percentage of loss by shrinkage or by insect pests; this is of great economic importance whether the corn is marketed directly as grain or indirectly through the feed lot as pork or beef. Soils are fertile and easily tilled; in the eastern sections, where rainfall is heavier and soils therefore more leached, moderate quantities of mineral fertilizers have long been used, a practice that has gradually extended to the western section as well. The topography of the plains is conducive to the use of large-scale machine operations in preparing the soil, cultivating, and harvesting (Illus. below).

Other geographic factors also contribute to the success of the Corn Belt farmers. The ingenious and inventive pioneers found this to be not only a land endowed with excellent soils and a stimulating climate, but also, especially in its eastern portions, a region with a wealth of mineral resources. Nature placed coal, petroleum, natural gas, and water power in and about this agricultural region. These are basic materials of industry. The result is a rural landscape of large, productive farms, dotted with industrial cities, from metropolitan size like Chicago and St. Louis, down to small centers, such as Muncie, Indiana, or Moline, Illinois. The cheap food supply, central location, and excellent transportation facilities are other factors favoring manufacturing.

Although the term "Corn Belt" is generally accepted as the designation for the area from Ohio to Nebraska and from southern Minnesota to northern Missouri, let it not be thought of as a one-crop country. Diversified farming is the general practice. Only 50 to 65 per cent of all the land in grain is devoted to corn at a given time. Wheat and oats, nitrogen-bringing crops such as soybeans or clover, and other forage crops all hold prominent places in the agricultural scheme. Most corn farmers are also hog and cattle farmers. Surveys have shown that 80 to 85 per cent of the cropland is used to produce feed for farm animals. A large percentage of the corn is fed to livestock without leaving the farm of origin. Furthermore, large numbers of cattle from the drier plains west of the Corn Belt are shipped in for fattening before going to market as finished beef. These conditions have made the Corn Belt the hog, cattle, and poultry belt as well.

Courtesy Soil Conservation Service

Harvesting corn by modern corn picker in Gibson County, Ill

They have also led to the establishment of numerous meat-packing plants in and about the region, the greatest centers being Chicago, Omaha, Kansas City, St. Paul, and St. Louis.

Important types of corn. At the outset of this discussion the cosmopolitan character of corn was pointed out. There are hundreds of varieties of this New World cereal. Some mature in 90 days or less from time of planting, while others require more than twice as long. Some are drought-tolerant, others require great quantities of moisture. Some do well on lowlands, others are best adapted to higher altitudes. Many are varieties of dent corn (so named because the top of the kernel collapses slightly during the ripening process). These find their most favorable natural conditions in the American Corn Belt. The latest great improvement in corn has been the production of hybrids with higher and more dependable yields than ordinary open-pollinated corn. In 1937, about 8 per cent of United States corn acreage was planted in hybrid; by 1938, Iowa passed the 50 per cent mark; by 1940, the entire Corn Belt passed the 50 per cent mark; and in 1946 Iowa plantings were 100 per cent hybrid, the Corn Belt, 91 per cent, and the United States, 67.5 per cent.

Flint corn, a hard, smooth type of corn, is less used than dent, though it is common in the Southwest and Mexico. *Popcorn* is one variety of flint corn.

Corn in Argentina. Argentina produces less corn than does the state of Iowa, yet it leads all countries in quantities exported. The corn-growing area centers around the lower Paraná region, mostly south and west of the river; lack of adequate transportation facilities and social factors have retarded its expansion into suitable lands located northeastward. The broad expanse of flat land in the Pampa is well suited to corn production by power methods. There are no trees or boulders to clear away and the soil is fertile and easily tilled (Illus. p. 88).

Climatically, the Argentine corn belt is not quite so highly favored as is that of the United States. While the annual rainfall averages only slightly lower, its distribution is less favorable and the danger of drought is greater. Not infrequently considerable rain falls during the picking season, thus interfering with the harvest and causing deterioration in quality. The winters are less cold and storage is more difficult. Transportation facilities and facilities for farm storage are inadequate in some of the corn-producing sections. This inadequacy multiplies the heavy losses through spoiling when rainy periods occur during the harvesting and marketing seasons.

Insect pests constitute another handicap to corn production in Argentina. Northwest of the grain country is a stretch of semiarid shrub- and bushland which serves as a vast incubator for locusts and other insects. When their numbers become exceptionally large, and the food supply of their native habitat proves to be inadequate, they sweep southeastward and feast on the grainfields of the Pampa. On such occasions the corn crop suffers heavily. The net effect of the various adverse factors is a striking fluctuation in corn production from year to year, at times amounting to over 400 per cent.

Argentina has, however, the advantage of producing the exportable surplus near the sea. Nearly all of the corn sold comes from within 200 miles of tidewater, and transportation costs therefore are low. The countries of northwest Europe are the chief buyers of Argentine corn. It is used there as feed for poultry and dairy cattle, and the small-kerneled flint corn is preferred. The small, dense, dry kernels of this type of corn with concentrated food value are best suited to shipping, too.

A major reason for the importance of Argentina as a corn-exporting country has been the lack of development of a hog-raising industry. Now that Argentinians have turned toward scientific improvement of their beef cattle and are finishing them into higher quality for the market, hog production is increasing, as hogs eat some feed wasted by cattle, and thus can be raised profitably along with the cattle. With continued and increasing attention to higher-quality beef production and with expansion of the swine industry, the local markets may be expected to absorb more corn. In normal years, more than three-fourths of the corn grown in the Argentine corn belt is exported. Expansion northwestward of the corn area is unlikely: the lesser rainfall there is more favorable for wheat than for corn. However, there are possibilities of eastward expansion into the Argentine Mesopotamia between the Paraná and Uruguay rivers.

Corn in Europe. The corn belt of Europe lies just north of the summer-dry Mediterranean area and south of the cool west coast marine area. The chief centers of production are the valleys of the middle and lower Danube and of the Po River, and southwestern Russia up to the Sea of Azov (Illus. p. 237). Chief producing countries are Romania, Russia, Yugoslavia, Italy, and Hungary. Northern Spain and Portugal and southwestern and central France also have moderate corn production. On the fertile lowlands, wheat and other cereals are raised nearly as much as corn, but on rough steep lands corn has great preponderance over other grains. Within this area corn is used as food for man and livestock. There, as in parts of the United States, the dependence upon it as a food is a criterion of the wealth of the consumer. Obviously the poorer mountaineers there, as in the southern Appalachians, use corn as their chief breadstuff, and in many cases use it also in the form of a strong liquor.

Although the middle and lower Danube plains are considered to be the very heart of the corn belt of Europe, production per acre averages low. In Romania and Russia, the two countries leading in production, the average yields per acre are only about 60 per cent of the average in the United States. The use of relatively poor slope lands or rather dry lands for corn production is of course an important factor in these results, but also cultural methods are to blame. In the Hungarian Basin, yields both in Hungary and Yugoslavia generally come up to the American average, while in Italy corn yields usually exceed this average. The entire area has the advantage of nearness to large European markets, and exports heavily to near-by countries.

Other corn regions. Corn production is of considerable importance in China, Brazil, India, the Netherlands Indies, Mexico, Egypt, Manchuria, and South Africa, but in all these countries, as well as in numerous ones of lesser production, most of the corn is consumed locally. The Union of South Africa, the Netherlands Indies, and French Indochina are among the minor exporters.

Though widely cultivated as a local subsistence crop, corn has restricted limits as a commercial crop. Long, warm summers with considerable rainfall, followed by autumns of little rain and winters severely cold, are the optimum climatic conditions. Where these are combined with large areas of productive land in conjunction with great markets for meat, corn comes into its own as the king of crops.

Oats

Oats constitutes one of the largest of the world's grain crops, the total production averaging more than 4¼ billion bushels yearly, compared with over 5 billion each for wheat and corn. But measured in pounds this is equivalent to less than 2½ million bushels of wheat, since a bushel of oats weighs but 32 pounds, whereas a bushel of corn weighs 56, and of wheat 60 pounds. Oats is used widely as food for humans and as feed for animals, particularly for horses. The plant is hardy and tolerant of a wide range of soil and climatic conditions, but is most extensively grown where moisture is relatively abundant, temperatures cool, and growing seasons comparatively short. The tolerance of oats for cool moist summers accounts for its prominence in northwest Europe, where it competes successfully with both wheat and rye. In the United States its adaptability is shown in its wide distribution; in the south it is occasionally rotated with corn and cotton, and in the north-central states it is rotated with corn, wheat, and tame hay, often replacing wheat, as in the northern Corn Belt. Kherson oats, a drought-tolerant variety, is grown in the Great Plains; moisture-loving varieties from Scotland and other North Sea countries are produced in the humid northeastern states.

Production and distribution. The three chief centers of world production are: (1) northern United States and southern Canada; (2) northwestern Europe; and (3) central and eastern Russia. In all these areas oats thrives under the diverse climatic and soil conditions and fits well into the agricultural practices. It provides both grain and forage feed, and the labor demands for planting and harvesting conflict little with those of wheat or corn.

The United States contributes about one-fourth of the world oat production; Russia, one-fourth; Canada, Germany, and France, each one-twelfth to one-tenth. Within the United States, oats reaches its maximum production in the northern part of the Corn Belt and beyond, extending northwestward into the spring-wheat region of Minnesota and the Dakotas, though in the Corn Belt soybeans are tending to replace it. The states leading in production are Iowa, Minnesota, and Illinois, the production of each generally ranging from 100 to 225 million bushels per year. In oats, as in corn, Iowa easily holds first place.

Although production is widely distributed in the humid intermediate countries where horses provide the power, international trade in oats is small. Ordinarily only 2 to 3 per cent of the world's crop enters the channels of international trade. The value of the straw for feed and the bulkiness of the grain militate against transportation and promote local production. Oats, therefore, has its chief markets near the districts where it is grown. Mills for preparation of breakfast cereals are important in this regard.

Barley

Barley was among the earliest cultivated cereals. Grains of the six-rowed species, believed to date back to predynastic periods, have been discovered in Egypt. For untold centuries barley has been the cereal depended upon by people who live near the desert's edge.

Uses and qualities. Barley ranks high in food value, but as a breadstuff it has failed to win high favor because its gluten content is too low for the making of soft, light bread. It is, however, widely used for soups, porridge, and specially prepared food for babies and invalids. In case of wheat shortage the use of barley offers a practical avenue of escape from a bread famine.

Barley is used extensively for making malt. For this purpose the grain should be plump, thin skinned, of pale color, and of high germinating quality. It should be rich in starch and relatively low in protein content. The color should be clear and uniform, because discoloration precludes its use in the making of malt to be used in the manufacture of beer, ale, or whisky.

Generally the chief use of barley is as a feed for domestic animals. Unlike oats, the straw has little value for feed and therefore is used chiefly for litter. The grain, however, makes good stock feed and yields 50 per cent more per acre than does wheat. It is in high favor as a forage crop for hogs, cattle, and horses, particularly where corn cannot be grown. In countries having winter rain and summer drought, as in California and Australia, it is often cut before the grain is mature, in order to use the whole plant as hay. Cured at this stage it makes an excellent fodder crop.

Range and centers of production. Barley can endure a wider range of temperature than can any other cereal. Because of its ability to ripen during a short growing season, it grows within the Arctic Circle in northern Sweden, Finland, and Russia. It is grown at altitudes varying from sea level to 14,000 feet and constitutes, for example, the principal grain crop on the high plateaus of Bolivia and Tibet. It is much more drought-tolerant than wheat and is therefore important in dry subtropical and tropical areas such as northern Africa and India, but it cannot stand as much rain as can wheat. While it is grown extensively in all countries of intermediate climate, it is the principal grain only where climatic conditions are unfavorable for wheat or rye, as at the edge of the deserts, near the cold limits of agriculture, and at high altitudes.

Among the continents, Europe holds first rank in barley production; the Soviet Union, Germany, Spain, and Poland are there the largest producers. The major centers outside Europe are China, India, northern Africa, Japan, Turkey, and north-central United States. China leads world production, the Soviet Union is second, and the United States is third.

International trade. International trade in barley is much more extensive than in either rye or oats. During the past decade 6 to 10 per cent of the world crop has entered export trade, the principal exporting countries being Romania, the Soviet Union, Canada, and Argentina. The principal importing countries are located in northwest Europe, where there are large demands for barley to be used for malt and for feedstuffs for dairy cattle. The importers, in order of volume, are the United Kingdom, Belgium, the Netherlands, and Germany.

Soybeans

The soybean bids fair to become an important crop in most humid middle-latitude climates. At present it is produced on a large scale only on the fertile lowlands between the Yangtze River delta and the Hwang Ho, in Shantung, in the Manchurian Plain, and in the Corn Belt of the United States. Botanically it is characterized by a large number of varieties, each of which is adapted to certain conditions of climate and soil. The length of the growing season required by these numerous varieties may range from less than three to more than six months. This flexibility makes the production of soybeans possible from Java to Northern Manchuria.

The bean is valuable as a food and a feed because of its high content of proteins and fats. In China and Japan soybeans are used for human consumption in many forms: sprouts, fresh or dried beans, meal for making noodles and other dishes, a cheeselike substance (the so-called bean curd), various sauces, and a source for the extraction of oil and the manufacture of bean cake.

Commercial importance. Commercially soybeans are most important for oil and for bean cake. The Manchurian Plain, at one time the principal producer, still is the main exporter. The oil is suitable for many industrial purposes, especially for the manufacture of oleomargarine, vegetable cooking compounds, paint, and soap. The residue, soybean meal, is pressed into cakes, and because of its high protein content it is valued as a feed and a nitrogenous fertilizer. In the United Kingdom, the Netherlands, and Denmark it is used extensively as a supplementary feed for dairy cattle, while Japan imports large quantities to serve as fertilizer on its rice fields and mulberry plantations.

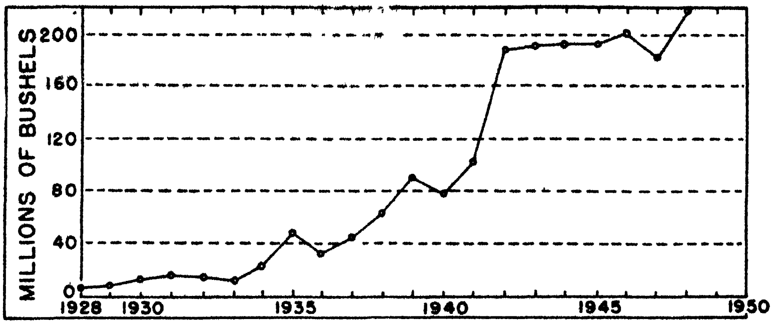
The striking rise of soybean production in the United States Corn Belt, particularly during World War II, has placed this country ahead of Manchuria and about on a level with China, as a leader of world production (Illus. p. 245). Soybean has caught up with cottonseed as the leading source of vegetable oil for margarine and cooking in the United States and far exceeds imported palm and coconut oils. The residual meal is an important cattle feed. The beans are raised in largest amounts in Illinois, Iowa, Indiana, and Ohio.

Sugar Beets

About one-third of the world's production of sugar is derived from sugar beets, a crop which can be grown successfully only in intermediate climatic regions, where the summers are neither too hot nor too humid, and where the growing season is at least 130 days long.

Extraction of sugar from the beets requires the use of large and expensive factories. Thus, the sugar beet is a strictly commercial crop which must be sold to a near-by plant. Much sugar cane, on the other hand, is raised both for home consumption and for commercial purposes.

Climatic requirements. The sugar beet has rather exacting requirements of climate and especially of soil. Summer temperatures should be moderate. In the United States it has been found that, in the regions most favorable for the cultivation of sugar beets, hot spells are rare and the average temperatures of the summer months (June, July, and August) do not depart much from 70°F. The supply of moisture must be ample, but a cool, dry period immediately preceding and during the harvest is essential for a high yield of sugar. The soil should be not only fertile but also deep and friable in order to allow the unhampered growth of the beet.



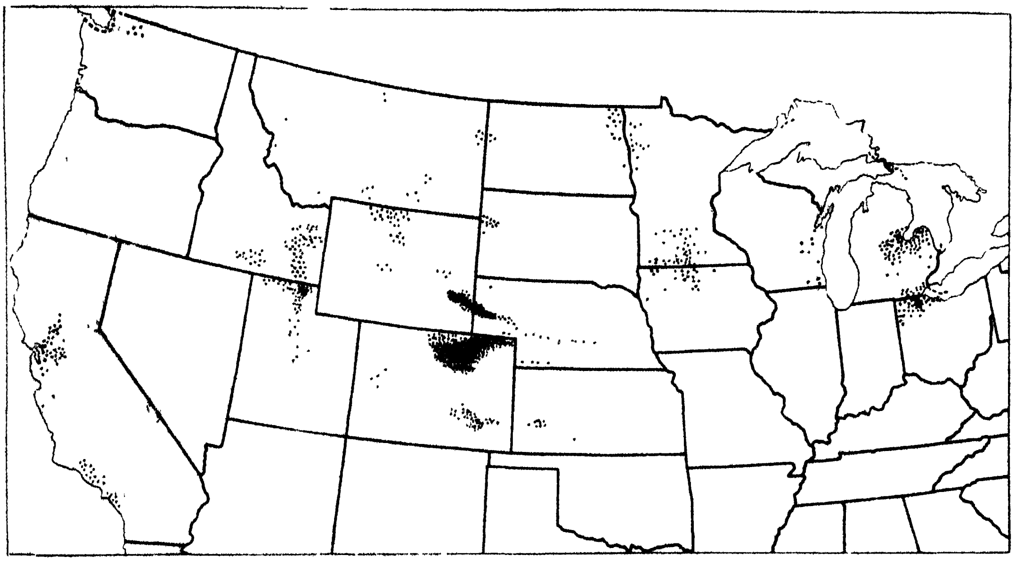
Production of soybeans in U. S. A. since 1928.

Principal beet-growing districts. Only Europe and North America have the ideal combination of physical and economic factors leading to important production of sugar beets. Europe accounts for more than 85 per cent of the world production of beet sugar. Beets are grown in nearly all European countries, but their cultivation is successful only on the most fertile soils, as, for example, on the loessal soils of northern France and Belgium, the Magdeburg district in Germany, Bohemia and Moravia in Czechoslovakia, and on the rich, black soils of the Ukraine in Russia. The countries leading in production of beet sugar in Europe are Russia, Germany, France, Poland, and Czechoslovakia.

In the United States, the cultivation of sugar beets is limited to the best glacial silt and clay loams east of the Mississippi and the unleached pedocalic soils of the semiarid regions farther west. Whereas in Europe the bulk of the crop is grown on nonirrigated land, in the United States the most important producing regions, with the exception of eastern Michigan and northwestern Ohio, are all under irrigation. The principal sugar-beet districts are the irrigated valleys of the Great Plains from Montana to southern Colorado, the Snake River Valley in Idaho, the Great Salt Lake Basin of Utah, and the Great Valley and southern coastal plain of California. Colorado and California usually are the largest producers (Illus. p. 246).

An intensive culture. The sugar beet is particularly well adapted to a system of intensive agriculture as practiced in most of Europe, since it requires deep plowing and careful tillage, the application of much manure and fertilizer, and the use of a large amount of cheap hand labor in thinning and weeding. In the United States, much of the labor is performed by Mexican immigrants. The by-products of the industry, beet tops and pulp, can be used to advantage in fattening cattle.

Beet sugar versus cane sugar. Since the yield of beet sugar per acre is generally lower than that of cane sugar, and the cost of production is much higher, almost all beet-producing countries protect their industry by means of tariffs against the competition of tropical sugar. Less beet sugar than cane sugar enters international trade. The principal exporters of beet sugar are Czechoslovakia, Poland, Germany, Belgium, and Hungary.



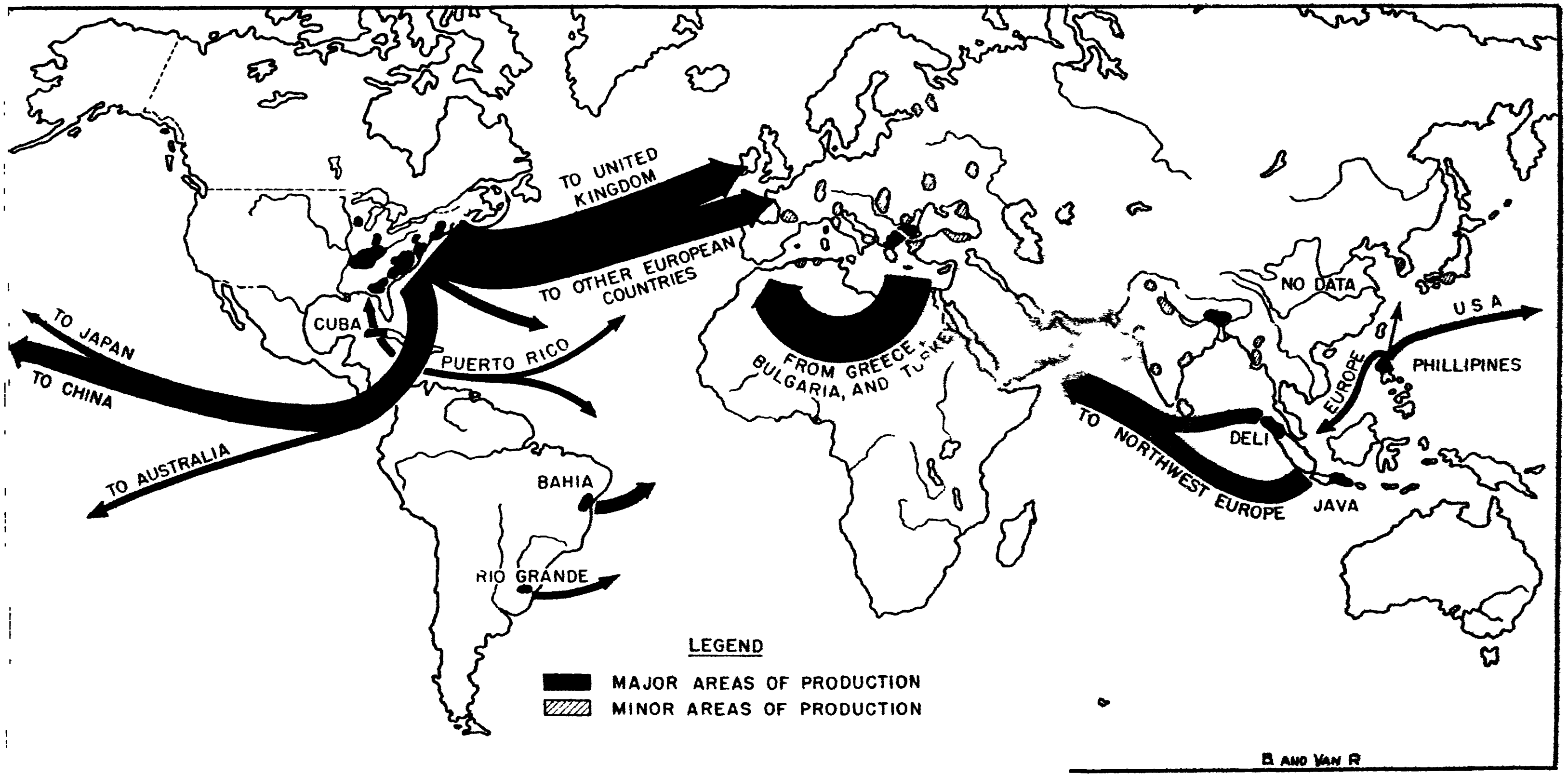
Prepared by Dr. Esther S. Anderson, Univ. of Nebraska.

Map of sugar beet districts in the United States.

Tobacco

Tobacco is truly a cosmopolitan crop, in regard to its consumption as well as its production. In some form or other it is used by practically all peoples of the world, and its adaptability to climatic conditions is such that it can be grown from the equatorial belt to the northern part of the middle latitudes: from Ecuador and Sumatra to southern Sweden and Canada. Obviously, tobacco is less dependent than are many other crops upon special conditions of temperature or length of growing season. However, the tobacco plant is a native of Mexico, Central America, and Brazil, and prefers considerable warmth and moisture; it does not thrive in a semiarid environment unless irrigated. Most of the major producing districts have developed in the southern part of the middle latitudes and along the northern margin of the tropics. Since the world's greatest commercial production is concentrated in the United States immediately north of the Cotton Belt, it appears justifiable to treat the tobacco industry in connection with the middle latitudes (Illus. p. 247).

The influence of soils. The geographic distribution of tobacco is influenced by soil rather than climate. The tobacco plant, esteemed for the flavor and aroma of its leaf, is like the wine grape, highly sensitive to slight differences in soil. The exact



Principal tobacco growing regions of the world and trade in tobacco properties of soil that affect the quality of the leaf are not well known, but experience has taught that some areas are better suited to tobacco than are others. As a result of this circumstance and of the economic inertia caused by established taste and purchasing habits, tobacco shows a spotted distribution notwithstanding its wide climatic range. Certain types of tobacco are rigidly bound to certain areas, and much of the tobacco of the world is sold on place-name specifications, as, for example, Maryland pipe tobacco, Virginia cigarette tobacco, or Deli cigar wrapper. It is interesting to note that an important center of Indian tobacco raising was located in Kentucky and Tennessee, an area which now is one of the principal producing districts of the world.

Curing of tobacco. The quality of the final product and, therefore, the uses to which the tobacco can be put are affected not only by soil, climate, and variety, but also by the mode of curing the leaf. In this country the trade recognizes three well-known classes based upon the methods used in curing the leaf: air-cured, fire-cured, and flue-cured. Air-cured tobaccos are treated in well-ventilated barns without the use of artificial heat. Fire curing takes place in barns about three to five days after the leaves have been hung. Open fires are made on the floor of the barn and kept burning for several days. The smoke of these fires affects the tobacco and gives to it a characteristic odor and taste. In flue curing, the heat and smoke are circulated through the curing house in large pipes or flues and do not come into direct contact with the leaves. A rather light colored tobacco results from this process.

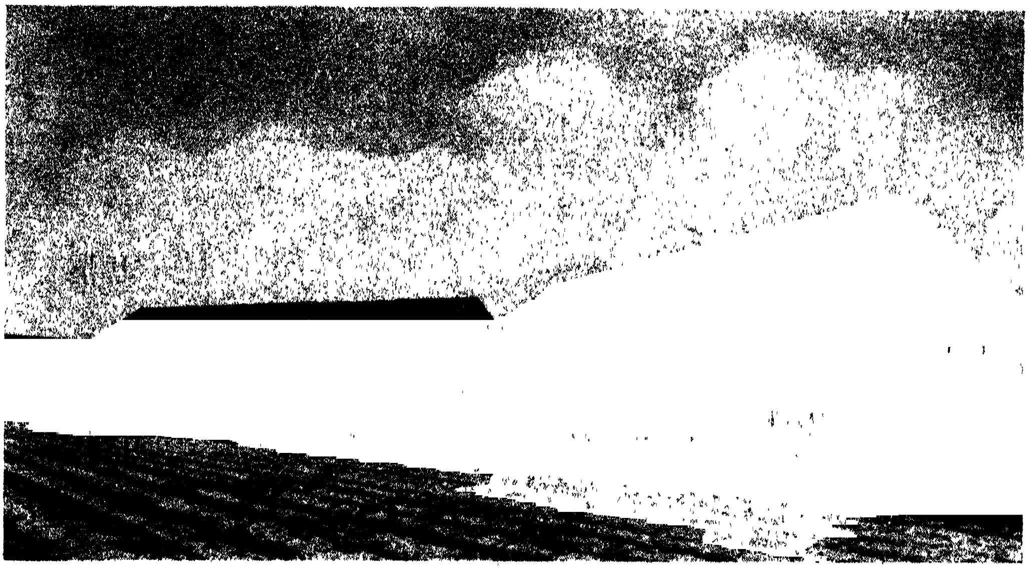


Photo by N. A. B.

Tobacco drying shed in Connecticut Valley. Bunches of tobacco leaf can be seen through the open doors.

Tobacco in the United States. *Flue-cured tobaccos* are grown on the light, loamy soils of the Piedmont region of North Carolina and southern Virginia and on the sandy soils of the Atlantic Coastal Plain of eastern North Carolina, South Carolina, Georgia, and northern Florida. Most of the flue-cured tobaccos are used in the manufacture of cigarettes. The development of the tobacco industry in these regions well illustrates how agriculture may be affected profoundly by changes in habits of consumption. The increase in the demand for cigarette tobacco has led to a great expansion of the acreage of flue-cured tobaccos, adding in relatively recent times the state of Georgia to the list of tobacco producers, and greatly enhancing the importance of the North Carolina and Virginia tobacco industry, which centers around Durham and Winston-Salem.

Fire-cured tobacco is produced in the Piedmont of central Virginia and in the extreme western parts of Kentucky and adjacent Tennessee in the so-called "black patch." Its use is relatively limited, and the acreage is slowly decreasing.

Among the *air-cured types* the Burley tobaccos of the Kentucky Blue Grass region and near-by areas stand first. These tobaccos are in demand primarily for pipe tobacco, but also for cigarettes. The darker and thicker leaves are used for the former, the lighter and thinner types for the latter. In the outlying districts of this area, in Indiana, Ohio, and West Virginia, a decrease in acreage is noticeable. In the southern part, however, the acreage is expanding.

Tobaccos used in cigar manufacture are also included in the air-cured group. In the United States the quantities involved are much smaller than are those of the cigarette and pipe tobaccos. The areas of production are comparatively small and are scattered through the states farther to the north,—Wisconsin, Pennsylvania, and Connecticut being the leading producers. The most interesting feature of this aspect of the tobacco industry is the growing of cigar wrappers in the valley of the Connecticut River and in Florida. For this purpose the leaves need to be thin, light colored, and large. Therefore, the plants often are grown under artificial shade of cheesecloth or laths. Connecticut Valley shade-grown cigar-wrapper tobacco sells for about ten times as much per pound as does dark air-cured tobacco, and about five times as much as flue-cured (Illus. p. 248).

Tobacco in Europe. In Europe much tobacco is grown locally, partly because in many countries the manufacture and sale of tobacco products has been made a state monopoly for revenue purposes. In the United Kingdom, tobacco raising is prohibited so that state control can be most effective. From a commercial point of view the principal producing regions lie in Greece, Bulgaria, and Turkey. There are grown the famous Oriental or "Turkish" tobaccos, especially prized for the manufacture of cigarettes. Among the best known are the tobaccos of Cavalla and Xanthe, grown on the north shores of the Aegean Sea (Illus. p. 247).

Other tobacco-producing centers. China and India are by far the largest producers in Asia, ranking in acreage and production next to the United States. Most of the tobacco, however, is consumed locally; only relatively small quantities of inferior quality reach world markets.

The Netherlands Indies rank next to the United States in commercial importance. In Sumatra, some of the choicest wrapper tobaccos of the world are grown on estates under European management, located on the fertile volcanic soils of the Deli region, where western initiative and eastern labor have transformed a tropical jungle into a flourishing agricultural district. The eastern half of Java also produces much cigar tobacco, partly on estates, partly on native lands.

The Philippines have long been famous for their excellent cigar tobaccos. "Manila" cigars are known the world over. The best tobacco, nearly all of cigar-leaf grade, is grown in the wide valley of the Cagayan River in northern Luzon.

The most valuable cigar tobaccos are grown in Cuba, Havana cigars being generally accepted as the world's best. The highest grade tobacco is grown in the Vuelta district of westernmost Cuba and in adjoining areas. Most of the crop is raised under protecting cheesecloth by a large number of small farmers.

Other important centers of tobacco cultivation are found in the states of Bahia and Rio Grande do Sul of Brazil, the former is well known as a center for producing tobaccos for cigar manufacture, the latter primarily for cigarettes.

Tobacco in international trade. The United States is the world's principal exporter of tobacco and tobacco products, in normal years sending more than two-fifths of its production abroad, mostly to Europe (Illus. p. 247). At the same time the United States imports (although in much smaller quantities, usually not more than 6 per cent of the domestic production) such types of tobacco as it cannot grow within its own borders.

The "Turkish" tobaccos of the eastern Mediterranean are exported mostly to western Europe and the United States. Nearly all the export tobacco of the Netherlands Indies is shipped to Amsterdam, where it is sorted and made ready for the auctions. A large percentage of these tobaccos of the finest quality reaches the United States. The Cuban exports, both cigars and leaf tobacco, go chiefly to the United States; the leaf is used in the extensive cigar-making industry at Tampa, Florida. The Philippine exports likewise consist of both cigars and leaf tobacco, for which the principal markets are found in the United States, Europe, and the neighboring Far Eastern countries.

The tobacco industry furnishes an excellent example of the great desirability and often the necessity of unhampered world trade. The differences in quality of tobaccos grown in various parts of the world naturally invite exchange, especially since extensive blending is practiced in both the cigarette and cigar industries. The United States, as the principal exporter, has probably the greatest stake in the maintenance and further development of the international trade in tobacco.

Flaxseed and Flax Fiber

In former times flax and wool were the principal materials used for the manufacture of clothing in all regions of temperate climate. Flax fiber lost much of its importance with the advent of cotton, and at present most of the flax of the world is of the variety which serves primarily for the production of seed, and which does not produce a fiber suitable for linen.

Flaxseed can be produced under greatly varying climatic conditions, but it generally does best on soils that have just been placed under cultivation. Large seed-producing regions are the Pampa district of Argentina and Uruguay, the states of North Dakota, South Dakota, Minnesota, and Montana, the Prairie Provinces of Canada, and India and Soviet Russia. Linseed oil, the oil of the flaxseed, is used extensively in the manufacture of paints and other products, and linseed cake is an important stock feed. Argentina and India are the only large exporters of linseed. The principal importing countries are the United States, the Netherlands, Germany, the United Kingdom, and France. The only important exporter of linseed oil is the Netherlands.

Fiber flax Flax produced for seed can stand rather high summer temperatures and even conditions of drought, but the production of fiber flax is carried on mostly in cool and humid regions. Practically all the fiber flax of the world is grown in Europe, where Russia is the principal producer. The bulk of the flax is raised in a belt between the region of black soils of the south and the coniferous forest of the north.

International trade in flax fiber is of relatively little importance. Much flax is still used for home consumption in Poland and Russia, but the best known centers of modern manufacture of linen are in Belgium, northern France, and the Belfast district of Ireland. Russia is the principal exporter.

Livestock

In nearly all lands domestic animals play an essential role in agricultural activities. This is true not only of agriculture as practiced in the more progressive countries, but also of the simple types of farming which still prevail in many parts of the world. The peasants of southeast Asia depend upon the water buffalo for the preparation of their rice fields, and the Negro farmers of the Sudan use the ox or the donkey wherever possible. Often the raising of domestic animals, even among primitive peoples, becomes an aim in itself. The Negroes of the east African plateaus consider a large herd of cattle as a tremendous social asset, while in parts of the far north, for example in Lapland, the entire economic life of the people may revolve around the reindeer herd. Domestic animals are often indispensable for purposes of transportation. In the tropics, where good roads and railroads are few, domestic animals, though little used for other purposes, are essential as draft animals and as beasts of burden. In the great tropical desert areas the camel is still the principal carrier of freight and passengers, although in some regions the autobus and caterpillar truck are becoming serious competitors.

The animal industries are best developed in the regions of intermediate climates. These regions produce the principal surpluses of animal products, and here horses, cattle, hogs, sheep, and poultry are of great importance in the agricultural scheme. In the polar regions the reindeer is the only domesticated source of food, and in the tropical latitudes the animal industries are handicapped by the nutritive deficient coarse grasses and by the numerous animal pests and diseases that abound in the warm, humid environment.

Horses

Domestic animals are kept for three major purposes: to provide men with food, material for clothing, and a source of power. The horse is without a peer for the latter purpose, and therefore throughout the centuries it has been the principal beast of draft and burden available to man. Although originally animals of the semiarid grasslands, they are now—because of their close association with tillage agriculture—most numerous in the regions of humid intermediate types of climate, especially in Europe and North America.

Distribution. The horse is not well adapted to warm humid climates. Where environmental conditions are unfavorable for horses their role is often taken over by other animals, as, for example, cattle in tropical India, camels in desert regions, llamas or yaks in the high mountains, and reindeer and dogs in polar areas. Even in the subtropics horses do not flourish. In the southeastern United States and in the countries around the Mediterranean, mules and donkeys are more numerous than horses.

Because of their efficiency as draft animals, horses have been essential to successful agriculture in the middle latitudes, and therefore, notwithstanding rapid mechanization of farming in some regions, most of the horses of the world are still found in the humid intermediate regions of Europe and North America. Horses have but slight importance as a source of meat or milk, except among a few nomadic peoples, such as the Kirghiz, where the milk plays an important role in the diet. Since they enter but slightly into national or international trade, they involve fewer phases of economic geography than do cattle, swine, sheep, or poultry, whose products furnish a great variety of commercial commodities.

Cattle

Two principal species comprise the bulk of the world's cattle: the taurine cattle (*Bos taurus*) and the zebu or humpbacked cattle (*Bos indicus*). The latter do well in the all-year-warm climates. Not only are they tolerant of high temperatures and great humidity, but also they are able to thrive on coarse forage; therefore they are raised in areas of seasonal droughts. In most regions no selection is practiced in breeding, and thus, as a whole, they are of limited value as beef or milk producers. However, they make strong draft animals. Their resistance to disease in their areas of occurrence is much greater than is that of taurine cattle, a characteristic particularly important in tropical regions where parasitic insects and microorganisms flourish. In southern

United States, especially in parts of Texas, zebus have been crossed with taurine cattle. The resulting breed has proved to be a fairly good beef animal which successfully resists the diseases carried by ticks and which can subsist on coarse forage.

In the low rice-growing districts of southern Asia the water buffalo (*Buffalo asiaticus*) is the principal domestic animal. It is thoroughly at home in a swampy environment, requires a daily bath, and likes to spend hours in the water with only its head and horns protruding. The water buffalo is neither a good beef animal nor a good milk producer, but its great strength makes it valuable for the laborious process of preparing the wet rice fields.

The taurine group, which includes a great variety of breeds, is best adapted to areas where mild to cold winters alternate with cool to warm summers. These are raised mainly in the middle latitudes.

Cattle raising. In many parts of the intermediate regions, and particularly in Europe, the raising of beef cattle, and often even small-scale dairying, is generally not a separate enterprise, but is integrated with a system of diversified tillage agriculture. The cattle consume those products which must be raised in the system of rotation but which are unfit for direct human consumption, such as legumes, grasses, and root crops. Their milk and meat are valuable farm products, while the fertility of the cropland is maintained partly with the aid of the animal manure. However, there are a number of regions in Europe where all other farm activities are subordinate to the production of milk.

Elsewhere, as in the Rio de la Plata region or in the American Corn Belt, the raising and fattening of cattle may be the principal aim of the farmer. In this case, tillage agriculture is carried on mainly for the purpose of producing feedstuffs such as corn and alfalfa, and the cattle convert these into commodities of higher value, such as steaks and roasts.

In still other regions, especially in the semiarid and arid lands, tillage agriculture is of little importance and the natural vegetation, which consists mostly of short or bunch grasses, provides the basis of an extensive type of cattle industry. In such areas, summer droughts often compel either the use of supplementary feed grown on irrigated land or migratory movements of the herds from winter quarters in low, snow-free plains to moist mountain pastures in summer.

The principal centers of cattle production are in the middle latitudes of Europe and North America. Important producing districts are also found in Argentina, Uruguay, Brazil, the Union of South Africa, and New Zealand. India has the world's greatest cattle population (including buffaloes) followed successively by the United States, Brazil, and the Soviet Union.

In some of these regions cattle are raised primarily for beef, while in others milk and milk products are of chief importance. Both the beef and the dairy industries figure prominently in national as well as international trade.

Among taurine cattle certain breeds are most valuable as meat producers, whereas others rank as better dairy animals. Important beef breeds include the Shorthorns, Aberdeen Angus, and Herefords, while the dairy industry is based largely upon the Frisian-Holsteins, Jerseys, Guernseys, and Ayrshires.

The beef industry. THE UNITED STATES. The raising of beef cattle is very important in the part of the Corn Belt west of Chicago. Large numbers of beef cattle are raised also on the farms and ranches in the Great Plains from Montana to Texas as well as in the valleys and on the mountain slopes to the westward. In the Corn Belt not only are large numbers raised locally, but additional cattle are shipped in from the regions farther west. These so-called "feeders" are finished for the markets on corn (Illus. p. 253). All through the Corn Belt, feed lots are characteristic features of the farms, particularly near the great meat-packing centers, which are, in the approximate order of their importance, Chicago, Omaha, Kansas City, St. Paul and St. Louis. Smaller but still important centers are Sioux City, St. Joseph, Indianapolis, Fort Worth, Milwaukee, Denver, and Oklahoma City. These markets furnish the bulk of the meat supplies for the densely populated industrial districts farther east. Exports of beef and beef products from the United States are not large, the trade with Hawaii, Puerto Rico, and Alaska surpassing that with foreign countries.

Courtesy Soil Conservation Service

A feed yard on a farm near Pilger, Stanton County, Nebraska The photograph shows part of a herd of 1,000 beef cattle that were being fattened for the market.

South America. In both Argentina and Uruguay the beef industry is a dominating factor in the economic life. Originally the development of the cattle industry was favored by the enormous landholdings and by the nutritious grasses of the Pampa. The mild winters, which make grazing possible throughout the year, proved to be an important asset. At present the production of high-grade beef in Argentina is to a large extent dependent upon the growing of alfalfa, which occupies an acreage only slightly smaller than that of wheat, and forms a valuable complement to the native grasses of the region. Because of their small populations, Argentina and Uruguay have large surpluses of animal products. Some of the low-grade beef, especially that from the neighboring Chaco, is made into meat extract and other products, but most of the beef prepared in the packing houses, or *frigorificos,* is high grade and is shipped in chilled or sometimes frozen condition to the great centers of consumption of western and southern Europe.

Australia. In Australia, the beef industry centers in the open forests and prairies of eastern Queensland. From there it extends southward into northeastern New South Wales and northward onto the sandy grasslands of the northern territory and adjacent portions of western Australia. Density of cattle is greatest in the region of the so-called Queensland Downs. Australia is sparsely populated and has a large surplus of animal products available for export. The country, however, was greatly handicapped by its distance from the principal centers of consumption in Europe. Much of the meat was shipped frozen, because of the long voyage through the tropics, and brought appreciably lower prices than the chilled beef from the Rio de la Plata countries. In recent years, however, with improvement of cooling facilities, there has been a considerable increase in the shipments of chilled beef. New Zealand also is an important exporter of beef. There the cattle industry is concentrated primarily in the low coastal plains of the two islands.

EUROPE. In most of Europe, north of the region of Mediterranean climate, cattle are numerous, but, with the exception of parts of Great Britain and Ireland and of some lesser regions, the raising of beef cattle is not an aim in itself: it is an integral part of a highly diversified system of agriculture. Beef cattle are usually fattened by using locally produced grass, hay, or other roughage, supplemented by grains, oil cake, and other concentrates, large quantities of which must be imported. As a result of the dense population, few countries consistently have an exportable surplus of beef. On the whole, Europe is an area of meat deficiency and forms the principal market for all the meat-exporting countries of the world.

The localization of beef and dairy industries. Beef cattle are relatively inefficient producers of food for human consumption. According to Gray and Baker[2] it takes 8.0 acres of cropland and 1.8 acres of humid pasture or its semiarid equivalent to produce a million calories of dressed beef.

From these figures it is evident that the specialized raising of beef cattle cannot be carried on economically in countries where density of population is high. In such countries, most of the land suitable for tillage purposes must be used for the direct production of foodstuffs. This, for example, is the case in Japan where pressure of population upon the land is so great that practically all cropland is too expensive for the production of beef. Generally speaking, a beef-cattle industry can be successful only in regions where population is comparatively sparse and where land is cheap. The British Isles are one of the notable exceptions, since Great Britain has been sufficiently wealthy to import large amounts of vegetable foods—and even additional quantities of meat—from abroad.

Only 1.7 acres of cropland and approximately 1.15 acres of humid pasture land or its equivalent are necessary to produce a million calories of milk or milk products. Thus, dairying, being a more efficient form of animal industry, can be carried on where population is dense and land fairly expensive, provided the conditions of the natural environment are favorable to dairy cows and at least some natural humid pasture land is available. In many of the more densely populated dairy areas, such as in the Netherlands and Denmark, supplementary feedstuffs must be imported. Dairying is also a successful pursuit in areas of relatively sparse population where—due to climatic conditions—the land is better suited for the production of feed and feed grains than it is for wheat and other foodstuffs, such as in parts of Wisconsin or northwestern France.

THE UNITED STATES. In the United States the most favorable conditions for dairy farming are found in the so-called hay and dairy region, which stretches from Minnesota through Michigan and eastern Ohio as far as Maine. Grass and hay are abundant, and all sorts of feedstuffs can easily be grown there. This entire area is advantageously located near the industrial regions of eastern United States. While dairymen in the states closest to the great urban centers, such as New York, New Jersey, and Massachusetts, devote most of their attention to the production of milk, in many instances shipped to the cities by special trains, in the states farther west a large proportion of the milk is manufactured into butter and cheese, which can stand some delay in shipment. The principal butter-producing states are Minnesota, Iowa, and Wisconsin (see page 238). Other important producers, all of approximately equal rank, are Nebraska, Missouri, Ohio, Michigan, Indiana, Illinois, and Kansas. Wisconsin makes half the cheese of the nation (Illus. above). Smaller dairying centers lie in the Puget Sound-Willamette Valley of western Washington and Oregon and in California. In the dairying regions of the northeast and in the Pacific Coast states much milk is canned in condensed and evaporated form. Considerable quantities of canned milk are exported to Cuba, the Philippines, Panama, and other countries in Latin America and the Far East, which, on account of a tropical or subtropical climate, produce little milk themselves. The exports to the United Kingdom also are considerable.

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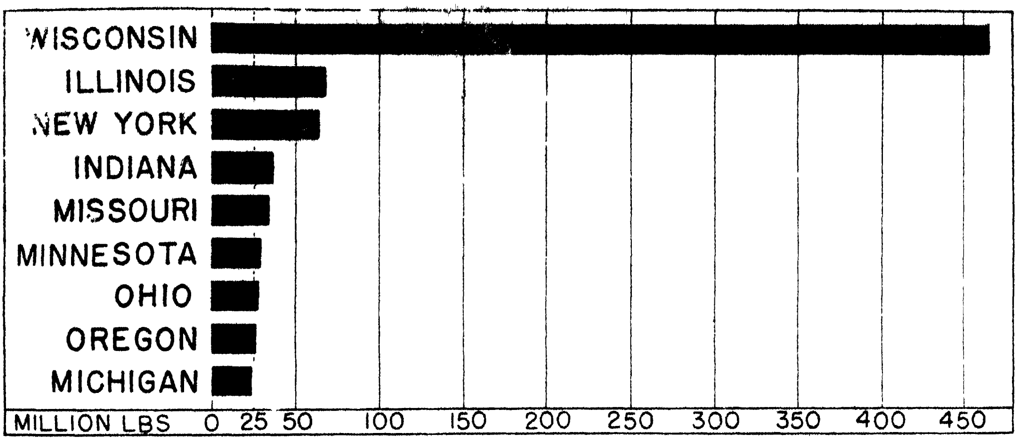
[2] L. C. Gray and O. E. Baker, "Land Utilization and the Farm Problem," *Miscellaneous Publication, No.* 97, United States Department of Agriculture, Washington, D. C., 1930.



Production of cheese in the principal producing states Average 1939-1945

Europe. In Europe the dairy industry is highly developed in the low-lying coastal areas from Brittany to southern Sweden and in the British Isles. These regions are subject to the direct influence of the westerly winds, and thus have a mild and moist climate which fosters the growth of luxuriant grasses and the production of feedstuffs.

The best-known dairy districts are in Denmark and the Netherlands. In the latter, the dairy industry is based primarily upon the succulent grasses of the "polders," the rich marine and alluvial lands which generally lie below sea level. The polders are surrounded by dikes, and the water table is regulated by either steam or electric pumping plants, or by windmills. Because of the number of cattle per acre it is necessary to import large quantities of supplementary feed, such as barley, linseed cake, and cottonseed cake or meal.

The Danish dairy industry also is highly intensive. It is dependent mainly upon feed crops, such as barley and artificial pastures of clover and hay. Furthermore, large quantities of feedstuffs, especially concentrates, are imported from abroad.

The success of the Netherlands and Danish dairy industries is largely due to the demands from the near-by industrial regions of Britain, Belgium, France, and Germany, which are made possible by the returns from mines, factories, and trading activities.

Other well-known dairy districts are the plateau and the Alps of Switzerland and the Po Valley of Italy. In Switzerland the high pastures above the timber line furnish excellent summer grazing. The principal center of dairy production, however, lies on the plateau along the north foot of the Alps.

Denmark and the Netherlands rank first in the Northern Hemisphere as exporters of butter. The Netherlands is the largest exporter in the world of condensed and evaporated milk, while the principal cheese exporters of Europe in the order of their importance are the Netherlands, Italy, and Switzerland, all three of which are noted for the excellence of their product.

NEW ZEALAND AND AUSTRALIA. In recent years New Zealand and Australia have developed an extensive dairy industry and have become major exporters of butter, following immediately after Denmark. New Zealand is normally the premier cheese exporter of the world. In Australia, the dairy industry is most important in the more humid coastal districts of Victoria, New South Wales, and Southeastern Queensland; in New Zealand, the industry is carried on mainly in the coastal plains of the North Island. Besides the countries mentioned above, Canada has become an important exporter of cheese.

Swine

Swine grow under widely varied types of environment. Some breeds of swine flourish in regions with distinctly tropical climates, as, for example, in the Philippines and in some sections of the Netherlands East Indies. Nevertheless, on a world map showing the distribution of swine, large areas will be found blank. This is not the result of a lack of statistical data but of the prevalence of religious taboos. Mohammedans, Hindus, and Jews are not allowed by the precepts of their religion to eat pork. Thus swine are scarce in India, the Near East, and most of northern and central Africa. The principal swine-raising regions are in countries of intermediate climate, especially in North America and Europe, although important production is also found in southern Brazil and China.

Distribution. In the United States the hog industry centers in the Corn Belt where the raising of hogs on corn feed forms the foundation of the entire agricultural scheme. While much of the processing of hogs is done in the great packing centers mentioned in the discussion of the beef industry, much is done also in smaller packing centers scattered through the entire Corn Belt. In Iowa, for example, Sioux City, Waterloo, Cedar Rapids, Mason City, Des Moines, and Davenport all have important packing industries.

In Europe swine are fed not only grains, especially barley and rye, but also potatoes and skimmed milk. Because of the latter the swine industry is often closely associated with the dairy industry, this being typically the case in Denmark and the Netherlands.

The principal exporters of pork and pork products in the order of their importance are Denmark (bacon), the United States (lard, ham, and bacon), the Netherlands (pork and bacon), and Poland (lard and bacon).

By far the major part of the United States pork exports are shipped to Europe, especially to the United Kingdom. Shipments to some Latin American countries are important also, particularly Cuba and Panama, the leading Latin American consumers of our pork products.

Sheep

Some breeds of sheep, such as the Merinos and Rambouillets, are excellent wool producers, while others, such as the Lincolns and Shropshires, are primarily meat producers. In recent decades a large number of cross breeds have been developed for the production of both meat and wool.

Since sheep can subsist and often flourish on rather coarse feed not relished by other domestic animals, most of the sheep of the world are raised in regions which are too dry, too stony, or too mountainous for other agricultural purposes. Sheep were often the mainstay of the pioneer, because they could easily be herded and the wool could stand the high costs of primitive transporta-

Courtesy Australian News and Information Bureau, New York

(A) Australian wool ready for export

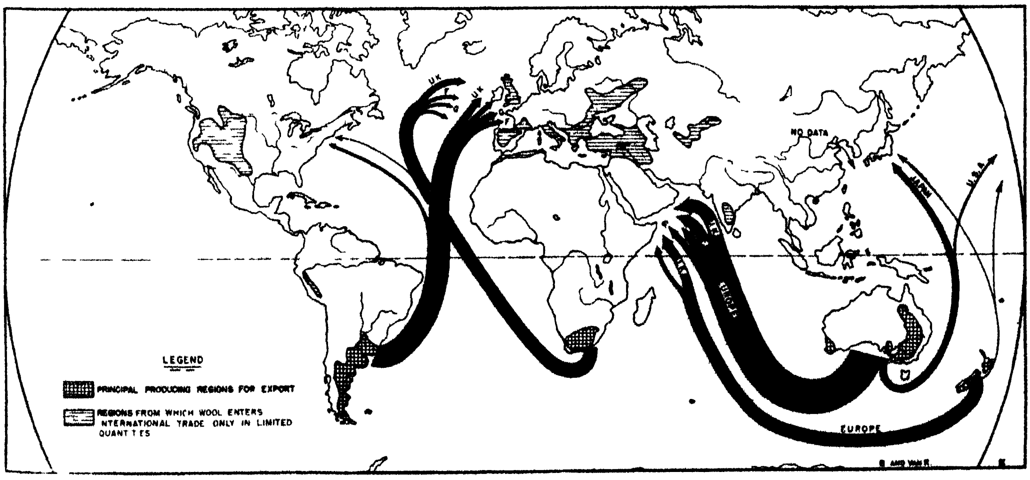
tion facilities or of transportation over long distances.

The principal sheep-raising regions of importance from the point of view of international trade are Australia, the leading country in sheep population, the Rio de la Plata region, in South America, the Union of South Africa, and New Zealand, all of relatively sparse population and with extensive areas of humid to semiarid pasture. However, large numbers of sheep are raised also in the United States, in the semiarid lands of southern U. S. S. R., in the Near-Eastern countries of Persia, Iraq, and Turkey, in Spain, and in Great Britain. In the most humid districts the mutton types predominate. In the dry lands, as in interior Australia, most of Patagonia, the high plateaus of South Africa, and the Spanish plateau, the wool-producing breeds are in the majority (Illus. herewith).

In the mountainous districts of southeastern Europe, sheep do well on lands poorly suited to tillage agriculture. However, none of the countries of this part of Europe have an appreciable export surplus of either wool or meat.

Great Britain has an exceptionally large number of sheep, owing in part to the extent of poor grazing country and in part to the popularity of mutton in the British diet. Because of the dense population, however, there is a large deficiency of both meat and wool.

Sheep in the United States. In the United States sheep are most numerous in the semiarid and mountainous range country west of the Great Plains, on the Edwards Plateau of Texas, and in hilly southeastern Ohio and parts of neighboring states. While formerly sheep of the wool-producing Merino and Rambouillet types predomi-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LEGEND
▦ PRINCIPAL PRODUCING REGIONS FOR EXPORT
▤ REGIONS FROM WHICH WOOL ENTERS INTERNATIONAL TRADE ONLY IN LIMITED QUANTITIES

(B) Principal wool producing regions of the world and the trade in wool.

nated in the United States, at present an ever increasing percentage is raised primarily for meat, and even on the western ranges production for both meat and wool is favored. In the semiarid ranching country of the west, sheep raising gives rise to regular migratory movements: from the winter grazing grounds in the desert areas to the high summer pastures of the mountains, most of which lie in the National Forests. Production of early lambs is important in many parts of the ranching area. The principal fattening and finishing districts for lambs are the valleys of the North and South Platte rivers in Colorado, Wyoming, and Nebraska, the Snake River district of Idaho and Washington, and the Great Valley of California. The latter produces winter lambs.

In the Corn Belt and the states farther east, sheep are less numerous and are bred mostly for mutton and the production of lambs. In western New York, central Ohio, and southern Michigan, "hot house" lambs have become an important source of income to the farmer. On the hilly lands of southeastern Ohio, fine wool sheep mostly of the Merino type are bred extensively.

International trade. The large exporting countries of wool and mutton all lie in the Southern Hemisphere: the Rio de la Plata countries, South Africa, Australia, and New Zealand. The exports of mutton are mostly destined for the British Isles. The wool is exported to the countries which are important centers of manufacture of woolen goods, principally the United Kingdom, the United States, France, Germany, Belgium, Italy, and Czechoslovakia. The Leeds-Bradford district in England is the leading woolen manufacturing district of the world.

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Chapter Fifteen

FORESTS AND FOREST INDUSTRIES OF THE INTERMEDIATE CLIMATES

THE GREAT FOREST AREAS OF THE world lie in the rainy tropics and in the regions of humid intermediate climate In those areas with humid subtropical climate important forest stands survive only in southern United States and certain sections of southern Brazil. In all other climatic regions forest vegetation plays a subordinate role. While in the rainy tropics the forest still dominates the landscape, due largely to factors discussed in Chapter Eight, in many parts of the regions of humid intermediate climate man has profoundly altered the natural landscape in his quest for tillable land, pasture, and lumber.

Forests

In those portions of the intermediate regions which are most favorable for agricultural development, the once extensive forests of deciduous hardwoods and of mixed hardwoods and conifers have largely succumbed to the axe of the woodman and the farmer. Even some regions which are marginal for agricultural purposes have been denuded of their stands of virgin timber. The most extensive deforested areas of the world lie in Europe south of a line which runs approximately from Oslo to Stockholm to Pskov, U. S. S. R., and from there to the Ural Mountains via Vologda and Vyatka; in the United States east of the Mississippi, particularly in the fertile areas of Ohio, Indiana, southern Michigan, southern Wisconsin, in parts of Kentucky and Tennessee, in large portions of the Piedmont and elsewhere; in part of Manchuria and adjacent areas to the south and southeast. In these areas a cultural landscape consisting of tilled fields and pasture lands with scattered stands mostly of second growth timber has supplanted the original continuous forest cover. Only mountainous regions little adapted to agriculture or regions of poor, sandy soils still have extensive forest stands. But little virgin timber, however, is left in these regions, and in many countries, especially in western and central Europe, these forest resources are carefully husbanded and so managed that sustained yields seem assured.

The northern coniferous forests. Farther poleward, where short growing seasons and poor soils hamper agricultural development but allow the growth of hardy conifers and a few types of deciduous trees, the forest still dominates the landscape. There, an immense belt of coniferous forests, which roughly coincides with the belt of subpolar climate, stretches across northern Eurasia and North America. In North America this belt is located mostly in Canada but occupies the northern half of Minnesota, portions of northern Wisconsin, much of northern Michigan, as well as the Adirondacks of New York and much of northeastern New England. Important southward extensions of coniferous forests are found in the mountains of Washington, Oregon, and California, in the Rocky Mountains as far south as New Mexico, in the Ural Mountains, and in eastern Asia. The only other extensive areas of coniferous forest are those of the southeastern states of the United States and the Paraná pine forests of southern Brazil (Illus. p. 88).

Southward the northern coniferous forests merge and mix with the deciduous stands of the milder intermediate climates. There conifers usually occupy the poorer soils and the higher lands with short growing seasons. Northward, toward the Arctic tundra, the stands gradually become less dense and the trees smaller, swampy areas with few or no trees become more frequent and more extensive, until finally only a few low and deformed individuals survive in the most sheltered places. Thus, from a commercial point of view, the southern part of the main coniferous forest belt is of the greater importance.

The forests consist mainly of relatively few types of coniferous or softwood trees, which generally appear in pure stands, this being markedly true of the pines and spruces.[1] The more tolerant types of hardwoods occur also, especially near the southern margin, although some species of birch and poplar extend far north. The latter often flourish where forest fires or indiscriminate cutting have destroyed the stands of conifers. In Canada, for example, large areas are occupied by aspen, a species of poplar.

Not all of the northern belt is, however, covered by forest vegetation. Northern Eurasia and northern North America both were heavily glaciated during the Pleistocene. This resulted not only in poor, stony soils, but also in poor drainage. Although the annual precipitation is small, evaporation is retarded by the prevailing low temperatures and in many sections seepage downward of water is prevented by permanently frozen subsoil. Therefore, much water is available for run-off. Because of the highly irregular glacial topography, however, much of the surface run-off collects in numerous swamps and peatbogs. On these, tree growth is either absent or badly stunted, and such timber as exists is useless for commercial purposes. Thus, of the approximately 2,485,000,000 acres of forest land in Soviet Russia, nearly 970,000,000 are estimated as consisting of large bogs and other unproductive areas, the bulk of which are located in the sub-Arctic belt. In Siberia, only 38 per cent of the forest area is considered actually to be forested In northern Sweden it is estimated that peatbogs devoid of merchantable timber account for 30 per cent of the total area. In the northern coniferous area of Canada similar conditions exist.

Lumbering. The lumber industry in much of the coniferous belt is carried on in a stern natural environment. Population is sparse, and agriculture often can survive only in close association with lumbering. However, some of the factors which handicap agricultural development are among the most valuable assets of the lumber industry, as, for example, the snow cover during the long cold winters and the spring freshets of the numerous rivers.

Cutting generally begins early in the fall, before the snow has become too deep. Where agricultural communities exist in proximity to the exploitations, as, for example, in Sweden, Finland, and Quebec, the farmer becomes a lumberjack for the winter season. Elsewhere, as in parts of Canada and northeastern European Russia, the labor must be imported and lumbering often becomes a large-scale enterprise requiring heavy investment in capital goods. The snow facilitates dragging the logs to the streams by horses or tractors. They are piled on the ice, and in the spring, when the melting of the ice and snow causes a brief period of high water, they are allowed to float down the rivers to where they can be sorted as to ownership and size, then processed in either sawmill or pulp factory.

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[1] The principal trees of the northern coniferous forests are: pine (*Pinus*), spruce (*Picea*), fir (*Abies* and *Pseudotsuga*), tamarack or larch (*Larix*), hemlock (*Tsuga*), and cedar (*Thuja*).

In some regions, particularly in Sweden, large amounts of capital have been invested in the improvement of these log "driving" ways. Rapids and shoals are eliminated; rows of floating logs are anchored along the banks and in the bends of the streams; flumes are constructed to secure a most efficient use of the spring freshets.

In northern Russia log-driving is handicapped because the majority of the rivers flow northward into the Arctic Ocean, and therefore the ice breaks up in the upper courses long before it does farther downstream. The floods which result may scatter the logs over the entire width of a valley. On the Pacific Coast of North America, much of the timber is too large, and most of the streams are too swift and contain too many falls and rapids, to make possible the use of this cheap method of transportation. Consequently, mechanical means of transportation must be used. Either donkey engines and cable traction is used or the timber is "catlogged," that is, dragged by caterpillar tractor to the nearest rail line. In most districts railroad systems, which may include narrow-gauge "feeders" and standard gauge main lines have been built to transport the lumber to the coast. With such equipment lumbering may be carried on throughout the year.

Principal centers of forest exploitation. Lumbering is carried on mainly in accessible areas which are relatively close to good transportation facilities. In Eurasia the principal centers of production for lumber and pulpwood are found in northern Sweden, Finland, and northern European Russia, especially the respective hinterlands of Leningrad and Archangel, Karelia, the regions to the north and northeast of Moscow, the central Ural area (the Perm or Molotov, and Sverdlovsk districts), and the Novosibirsk, Krasnoyarsk, Irkutsk, and Khabarovsk regions of Asiatic Russia. In Canada the provinces of Quebec, Ontario, and British Columbia have the largest annual timber cut.

Large parts of the northern coniferous forest belt, especially in Siberia and in western interior Canada, are so far from the areas of consumption and have such poor transportation facilities that at present commercial exploitation is impossible.

Timber resources and forest exploitation in the United States. In the United States the original immense resources of hardwoods and softwoods have been greatly depleted, partly because vast areas have been cleared for agricultural use, partly because much land unsuitable for agriculture was so completely stripped of trees by the lumber industry that restocking by natural means became an exceedingly slow process. In the areas of coniferous forests, especially, what was left by the lumberman in many instances was destroyed by fire, and as a result low grade hardwoods subsequently took the place of the valuable softwoods. It is estimated that in the United States forests of commercial value—both hardwoods and softwoods—originally covered an area of roughly 820 million acres. Today the acreage of virgin growth of saw timber—mature forests not seriously disturbed by cutting, fire or insect and disease infestations—is about 45 million acres. The only areas where considerable stands of virgin timber still exist are the Cascades, the Sierra Nevada, the coastal ranges of Washington and Oregon, and the Rocky Mountains. The Pacific Northwest has 18,500,000, the Rocky Mountains 14,400,000, and California 8,400,000 acres of such forest. Little virgin timber is left in the forested portions of New England, New York, and the Lake States, and even in the Atlantic and Gulf coastal plains such stands now constitute only a small percentage of the forest area (Illus. p. 263).

Fortunately, a considerable acreage of second growth has reached saw-timber size. *Saw timber* denotes merchantable trees which are large enough to yield logs for lumber. Their minimum size varies from 9 to 23 inches diameter at breast height, depending upon species and region. The total acreage of second-growth saw timber is about 160 million acres, of which 43 million are in Florida, Georgia, Alabama, Mississippi, and Tennessee, 31 million in Arkansas,

TABLE VIII

COMMERCIAL-FOREST AREAS OF THE UNITED STATES BY MAJOR TYPES OF GROWTH AND REGION 1945

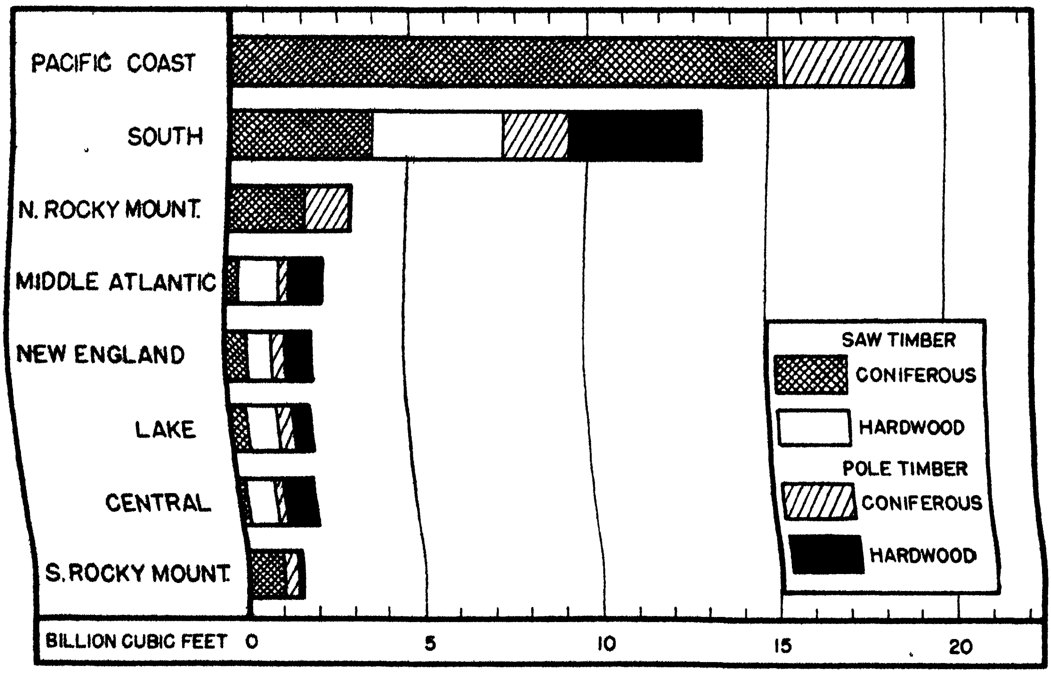
	Total 1,000 acres	*Saw-timber virgin growth 1,000 acres*	*Saw-timber second growth 1,000 acres*	*Pole timber 1,000 acres*
Pacific West	62,609	16,919	10,276	10,899
South	183,266	973	97,404	29,322
North Rocky Mt.	29,066	7,292	4,699	9,913
South Rocky Mt.	15,782	7,145	2,272	3,454
Central . .	44,213	230	11,706	10,049
Lake . . .	50,345	1,510	4,960	9,505
Middle Atlantic	41,586	161	14,652	12,714
New England	30,851	188	13,707	8,116
United States	461,044	44,618	160,558	95,013

Source: Forest Service, U. S. Department of Agriculture.

Louisiana, eastern Texas and adjacent Oklahoma, 23 million in the Carolinas and Virginia, 14 million in New England, 15 million in the Middle Atlantic States (New York, Pennsylvania, New Jersey, West Virginia, Maryland, and Delaware), 11 million in the Central States, and 5 million in the Lake States. A graphic picture of the present distribution of mature timber land in the United States is given below.

Besides these areas of merchantable saw timber there are fairly considerable acreages of *pole timber*, characterized by trees which are too small for saw logs, but large enough for cordwood, and of small-dimension saplings and seedlings. (See Table VIII.)

The forests of the Northwest and of California consist almost entirely of coniferous trees, among which the Douglas fir (*Pseudotsuga taxifolia*) and the western yellow pine (*Pinus ponderosa*) are of major importance (Illus. p. 263). The Pacific states are responsible for more than one-third of the



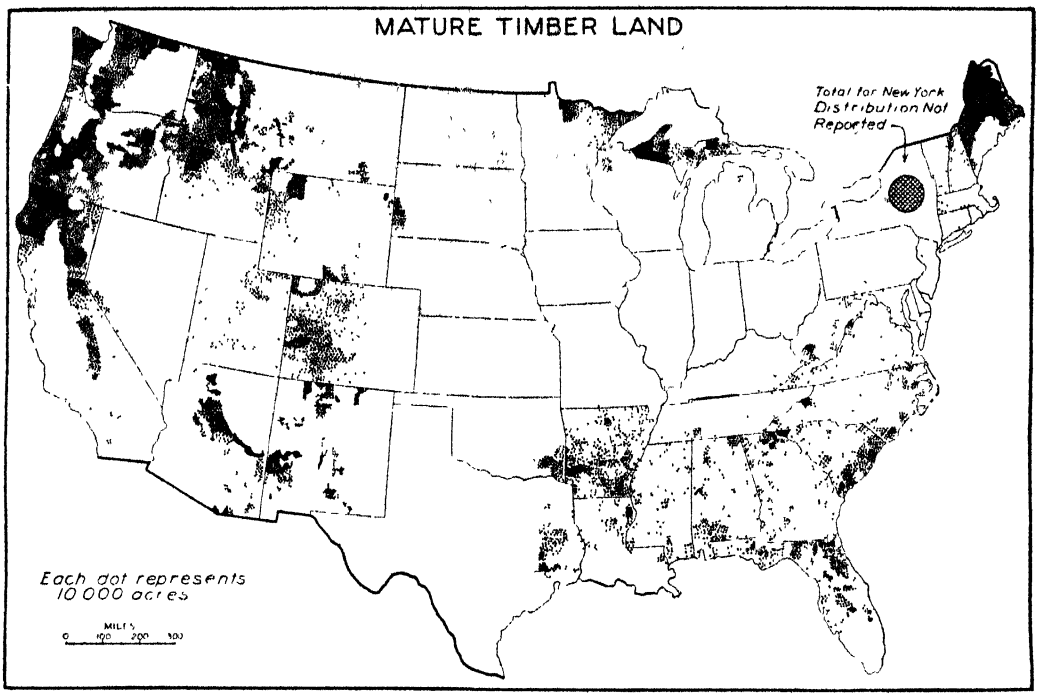
Source: Senate Document No. 12, Seventy-third Congress, First Session, Washington, D. C., 1933

Total stands of timber in the forest regions of the United States.

entire softwood production of the United States.

As a producer of both softwoods and hardwoods, southern United States still holds first place. The area occupied by commercial forest land in the South (Virginia, Tennessee, Arkansas, southeastern Oklahoma, eastern Texas, and other southern states) is estimated at 183,000,000 acres, or nearly 40 per cent of the total for the United States (Illus. p. 262). Of these, 973,000 acres, less than 1 per cent, bear virgin saw timber, the remainder consisting of second-growth saw timber, cordwood stands, and cutover areas. The stands available for commercial purposes in all of the south are only about two-thirds of those in the Pacific states, those of saw timber about half. Since in this area total annual drain of saw timber exceeds natural annual growth, the utmost efforts should be exerted to protect and manage the forests of this region in such a manner that the annual natural growth may be almost doubled. This is entirely within the bounds of possibility, as large portions of the south have very favorable growing conditions and much land is better suited to forest than to crop use.

The Pacific Coast area has the most extensive stands of virgin saw timber left: 27 million acres, or 60 per cent of total acreage (Illus. p. 262). The Rocky Mountains are next with a little over 14 million acres. However, half of these virgin stands in the Rocky Mountains and in California are of poor quality. The best virgin stands are in the northwest, where on one-third of the total virgin forest area is concentrated 57 per cent of the total volume of virgin timber. In many parts of the west the annual drain greatly exceeds annual growth. Excessive cutting of virgin stand, premature cutting of second-growth timber, heavy depletion


MATURE TIMBER LAND
Total for New York Distribution Not Reported
Each dot represents 10 000 acres
MILES
0 100 200 300

Courtesy U. S. Forest Service.

Distribution of land supporting timber currently marketable for the major forest products. Does not include second-growth stands cut for minor products. Published in Part VIII of the Supplementary Reports of the Land Planning Committee, National Resources Planning Board.

due to fires and insect damage, and prevalence of conditions which hold back natural growth are largely responsible for this situation. Fortunately, fairly extensive areas are owned or managed by the federal government, or by state, county, or municipal governments (over half in the Northwest and California, over three-fourths in the Rocky Mountains) under long-range development plans. As the virgin stands in the United States are nearing exhaustion, it is now advisable and soon will become necessary to adopt policies of scientific forest management for all our forest land, similar to those practiced in Europe and on some of our national forest lands, in order to maintain a dependable supply of timber.

Courtesy American Forest Products Industries.

A good crop of hardwood logs being loaded on a train in Arkansas. Nearly half the hardwood lumber production in the United States is oak, followed by red gum and yellow poplar. The tier of states from Virginia to Arkansas produces most of our hardwood.

Timber resources and forest exploitation in Canada. Canada, except for the extensive treeless tundra regions of the north, the prairie provinces in the central west, and a small region of original hardwood forests in southernmost Ontario, lies wholly within the great northern coniferous belt in which hardwoods play a subordinate role (Illus. p. 88).

It is estimated that Canada possesses 1,290,000 square miles of forested land. However, a large proportion of this land is nonproductive and will probably never be productive, as natural conditions are so unfavorable that the trees cannot reach merchantable dimensions. Of the forest area, 37 per cent is classified as nonproductive, leaving a total area of over 800,000 square miles of productive stands. Of this a little less than half carries merchantable timber, the remainder is young growth. Owing to the size of the country there are many regions where the timber is so inaccessible that it cannot be profitably exploited within the near future. The accessible saw timber is located especially in British Columbia, Quebec, and Ontario, with stands of smaller extent in New Brunswick, Nova Scotia, and the Prairie Provinces. The major producers of lumber are British Columbia, Quebec, and Ontario. The principal coniferous species cut are Douglas fir, spruce, and balsam fir, with smaller quantities of hemlock, white and red pines, cedar, Jack pine, and lodgepole pine. Among the hardwoods, birch and maple are most important, though hardwood production usually constitutes only a little over 6 per cent of total lumber production. The largest accessible reserves of saw timber are spruce and balsam fir (104 billion board feet), chiefly in Quebec, British Columbia, and Ontario; hemlock (27 billion b.f.), chiefly in British Columbia; cedar (26 billion b.f.), in British Columbia; Douglas fir (24 billion b.f.), also in British Columbia; Jack and lodgepole pine (19 billion b.f.), primarily in Ontario; and white and red pine (9 billion b.f.), especially in Ontario and Quebec.

Courtesy Caterpillar Tractor Co

End of journey. Redwood logs being hauled from mill-pond to sawmill in Marin County, California

World lumber trade. The bulk of the timber which is cut in the middle latitudes is used for lumber and fuel, and smaller quantities are used for pulpwood, veneer logs, hewn ties, fence posts, mine timbers, shingles, and other purposes. In the majority of the countries which are located in the intermediate and subtropical climatic regions, consumption exceeds production and large imports are necessary. This is especially true in Europe. For example, in Great Britain only 5.4 per cent of the land area is in forest, in the Netherlands 7.8 per cent, and in Belgium, France, and Italy about 18 per cent. All of these countries are heavy importers. Germany (old boundaries), with 27.5 per cent of its area in forest, ranked as the second major European importer before World War II. This condition gives rise to an important trade in wood and wood products. As softwoods are easily workable and suitable for many purposes, they are in great demand all over the world. Normally, for example, appreciable quantities of northern softwoods are imported in all of the African colonies which have vast areas of tropical forest. It is often cheaper to lay down softwoods from Canada, Sweden, or the United States in the ports of the Guinea Coast than it is to obtain tropical hardwoods from the interior. Thus, the countries which have extensive stands of coniferous forest dominate the world's trade in wood and wood products. The principal exporters are those countries which have a share of the great sub-Arctic belt of coniferous forests: Canada, Sweden, Finland, and the Soviet Union. The United States, although importing annually from one to two billion board feet for various purposes, in normal years exports from two to three billion board feet.

While in the past most of the lumber entered world trade as roughly hewn logs, now it is generally shipped as lumber. Some producers export even semi-manufactured and finished products, such as plywood, roof shingles, doors, and window frames.

Wood Pulp and Paper

During the last half century the paper industry has become an important consumer of wood, since most of the paper used in the world is now made of wood fiber. As a result of lower cost of manufacture of paper stock, and in response to the greatly increased output of books, magazines, and especially of newspapers, the requirements of the paper industry have grown enormously. Also the rayon or artificial silk industry uses wood pulp, in this country especially the pulp made from spruce and western hemlock. The plastics, cellophane, fiber board, and related industries also use increasing quantities of pulpwood and. wood waste. For the manufacture of wood pulp, trees below saw-timber size can be used. This gives a greater measure of economic security to pulp-wood plants than to the ordinary sawmill enterprises, as under careful management suitable timber can be maintained within reach of the plant.

Soft coniferous woods, low in resin, such as spruce and hemlock are preferred for the manufacture of pulp for paper making. In recent years manufacturing processes have been improved to such an extent that the number of usable species has increased greatly. Southern yellow pine is now one of the major sources of pulpwood. Poplar, balsam fir, Jack pine, white fir, beech, birch, and maple are other species in current use.

The wood is reduced to pulp either by purely mechanical means or by cooking under steam pressure and with an admixture of chemicals. All of the newsprint and other cheap grades of paper, which do not need to be of great strength or of pure white color, are manufactured from mechanical pulp, though usually with an addition of sulphite pulp. The chemical processes eliminate a large part of the lignin or wood substance, leaving mostly cellulose. They are more expensive than the mechanical processes and yield smaller amounts of pulp, which is, however, of longer fiber and can more easily be bleached. The sulphite process, which consumes chiefly spruce and hemlock, is used in the better grades of paper, as, for example, book or magazine paper. The sulphate process is employed for the production of strong brown wrapping or Kraft papers from resinous woods such as those of the southern pines. The soda process is applied to hardwoods, as aspen and yellow poplar. Soda pulp is generally mixed with sulphite pulp for the production of medium and better-grade papers. In the United States mechanical and sulphite pulp constitute two-thirds of the total requirements.

Pulp production. The pulp industry depends not only upon large amounts of cheap woods but also upon the availability of cheap power. Thus, the industry is located mainly along the southern edge of the coniferous forest belt in America, and along the coasts of Sweden, Finland, and Norway, where raw material is abundant and where water power can be easily developed because of the glacial topography. The principal producers of wood pulp are the United States, Canada, Sweden, Germany, Finland, Norway, and Russia.

At present, pulpwood constitutes nearly 11 per cent of the cut of all timber products in the United States. The principal pulpwood-producing regions are the South and the Pacific Northwest, followed at a considerable distance by New England and the Lake States. Manufacturing plants in the older producing regions (New England, Middle Atlantic, and Lake) face a major supply problem as the quantity of available raw material has become insufficient to meet the demands of the factories. In the South, competition with the lumber industry for available timber is a serious problem, while in the Northwest, Sitka spruce stands are declining and there is increasing competition with the lumber industry for hemlock. Because of the depletion of the local resources, over a million tons of wood pulp and from 2½ to 3 million tons of newsprint paper have to be imported annually from Canada. In Canada, about 30 per cent of the cut of all timber products is pulpwood. The provinces of Quebec and Ontario rank first as pulp and paper producers, but the industry has also established itself on the west coast, near the extensive forests of British Columbia.

While large quantities of wood are still available both in the more and in the less accessible parts of the northern coniferous belt, the rapid depletion of the virgin stands in several regions will make it urgently necessary to inaugurate everywhere policies of forest conservation such as are now practiced, for example, in Sweden and Finland. This is desirable not only because the wood consumption of the world is increasing steadily, but also since, on much of the land under coniferous forest, timber is the only profitable crop.

Furs

The northern coniferous forests are the abode of numerous fur-bearing animals, varying in size from weasel to bear. The hunting and trapping of these animals provide a welcome source of cash income in many regions where returns from agriculture are small. Farther poleward they develop into an industry to which the population may devote most of its time.

The longer and colder the winters are, the better generally is the quality of the fur. Inasmuch as agricultural settlement with its attendant depletion of wild life has penetrated only the southern fringe of the great northern coniferous forests, they still harbor large numbers of valuable fur animals, as fox, weasel, sable, mink, muskrat, and beaver.

The small bulk and high value of most furs are sufficient to offset the slow and expensive transportation which is typical for sparsely populated areas. For that reason the trapper has usually preceded the lumberman and the farmer in the settlement of forested territory. The role which the fur trade played in the establishment of British dominion over North America is well known, but the significance of the same trade in extending Russian influence in Asia is not so well known. The early expansion of the Russian empire from the Urals to the shores of the Pacific, and at one time even into Alaska, was due largely to the eastward and northward advance of the trapper in the trackless wilderness of Siberia.

Principal fur-producing countries. Russia is undoubtedly the largest producer of raw furs in the world. Although the domestic consumption is high because of the severe winters, nevertheless furs have always been important as an export item. Canada likewise is important both as a producer and as an exporter of furs. The provinces of Quebec and Ontario, and the Northwest Territories, usually lead in value of produced pelts. In many sections of the northern forest region the outposts of the Hudson Bay Company are still the only nuclei of settlements. Among other fur-producing regions should be mentioned Mongolia, Manchuria, and northern China.

The United States not only produces much raw fur but, as a result of the high standards of living, is the principal fur-consuming country in the world. The value of the imports generally far exceeds that of the domestic production. As settlement spread in the United States, and more and more of the forest was turned into agricultural land or was destroyed by the lumber industry, the number of valuable fur animals greatly decreased. Where the Indian had been accustomed to husband carefully the resources of wild life on his hunting grounds, the hunting and trapping by the white man often degenerated into a process of virtual extermination. Nevertheless, and thanks mostly to a policy of conservation of wild life adopted by the states and fostered by the federal government, the total catch of fur animals is still estimated at from 40 to 70 million dollars per year. Among the fur-producing districts, the lower Mississippi basin stands high, while considerable numbers of fur animals are also trapped in the coniferous forest regions of northern United States. St. Louis is a large fur-collecting center, and New York City ranks as a great world market.

Fur farming. As a result of the gradual retreat of wild life before the advance of white man, and the increasing popularity of fur clothing, it has become profitable to raise certain kinds of fur animals, especially silver fox. Fur farming is practiced extensively in northern United States from New England to the Pacific Coast. In southern Canada it has also become an important industry. The practice has likewise been introduced successfully into several European countries.

Rabbits are raised in many countries, both for skins and for meat. The skins, which by various processes of manufacture can be made to resemble more expensive furs, play an important role in the international fur trade, Australia being the foremost exporter of this commodity, which is also used for the hair.

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Chapter Sixteen

THE POLAR CLIMATES

BEYOND THE MIDDLE LATITUDES winters expand to include all or most of the year; ice and snow grip both the land and the ocean. In the polar climates, freezing temperatures occur in all months of the year, and the average temperature even of the warmest month remains below 50°F. The summers, though occasionally bringing warm days, are so short that their influence is entirely overshadowed by that of the long unbroken winter. The bleakness betokened by ice and snow is the predominant aspect of the landscape.

Even along the warmer margins of polar climates, the prevailing low temperatures prevent the growth of tall trees. Although during the brief summer the upper soil may thaw out to a depth of one to three feet, the subsoil remains frozen throughout the year. Most of the precipitation falls as snow and, measured in inches of water, is so small that the polar regions would be distinctly semiarid if the temperatures were higher. Two principal types of climate can be recognized: the *tundra*, characterized by a short summer which makes possible the growth of low vegetation; and the *ice-cap* type, where the ground is never free of snow and ice and the higher forms of vegetation are entirely absent (see World Map of Climatic Regions).

The Tundra

The tundra is extensive in the Northern Hemisphere, but in the Antarctic it is limited to a few small islands scattered through the southern part of the oceans.

The term "tundra" is derived from the Finnish *tunturi*, which means a flat, barren plateau. In usage, the meaning of the word has gradually broadened to embrace the treeless, steppelike areas covered with a vegetation of mosses, scanty grasses, and sometimes low shrubs, which are so characteristic of the far north, and also to designate the climate typical of these regions (Illus. p. 270).

The tundra includes all areas where the average temperature of the warmest month is below 50°F. but above freezing (32°F.). It forms a belt of varying width that surrounds the Arctic Ocean, stretching over nearly ten degrees of latitude in the Taimir Peninsula and in extreme northeastern Asia. The total land area included is vast, being variously estimated at three to five million square miles. The edges of the tundra are located along the southern border, projecting far southward on upland areas and receding northward in the major stream valleys. In North America the tundra extends from northern Alaska to northern Labrador, including the so-called Barren Grounds northwest of Hudson Bay.

Climatic conditions. Winter, the dominant season, is a period of darkness as well as of cold. In the southern parts the sun shines but two or three hours a day during midwinter, and in the northern parts it does not appear above the horizon for several

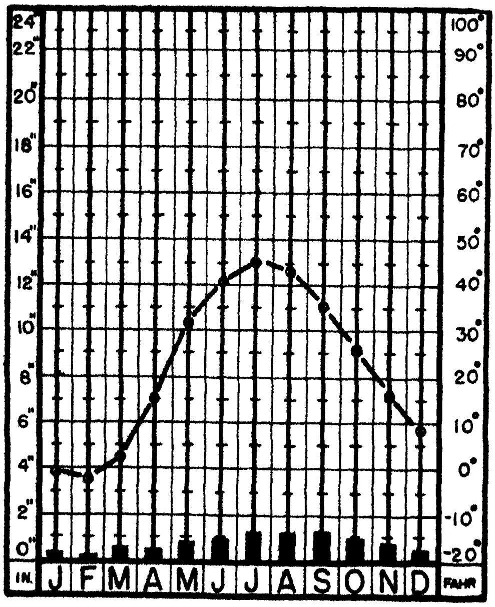
Courtesy Alaskan Branch U S Geological Survey

(A) Tundra in Alaska Note swampy conditions and boat being towed along small channel The men are wearing mosquito nets to protect themselves from insects

weeks. Temperatures of —40°F. are common, and often they fall still lower The snowfall, though not heavy, blankets the frozen ground On the other hand, summers are short and featured by almost continuous sunlight, and in some of the more continental areas temperatures mount to unexpected heights. Summer maxima above 80°F often occur where in winter the temperatures drop to —60°F. or lower (Illus. at right).

Even greater extremes occur in some places, as, for example, at Fort Good Hope in northern Canada, where summer maxima of 95°F. and winter minima of —79°F. have been recorded. Spring may not come until June, and then only as a brief transition period from winter cold to summer warmth. Autumn is an equally short period, in late August or early September, when the warmth and flowers of summer are displaced by cold blasts introducing the long winter. Spring and autumn are so brief and temperatures so variable that they bear little resemblance to their counterparts in the middle latitudes.

Most of the precipitation falls as rain or snow in summer or early autumn, when daytime temperatures are generally well above the freezing point Although not heavy, often averaging less than 10 inches



(B) Tundra climate Average temperature and precipitation, Jacobshavn, Greenland Altitude 40 feet, total precipitation 9 inches during the year, most of the precipitation becomes soil moisture because of the flatness of the tundra lands and the low rate of evaporation. During much of the summer, the relative humidity is high, 70 per cent or more, and thick fogs are characteristic of the early part of this season in most of the coastal areas and often far inland.

The long summer days, with continuous sunshine for weeks, as is the case beyond latitude 68°, constitute a period of weather which people of lower latitudes usually do not associate with polar climates. Sunshine uninterrupted except by occasional clouds, temperatures warm enough to be pleasant, a landscape verdure-clad and in some of the more favorable spots flower-bedecked, characterize the midsummer weeks. But this season is so short that at its height people begrudge themselves the time for sleep. And then the long polar winter comes. Although the winter is a period of intense cold, raging storms, and great hardships for man, it is not without its compensating features. Along the southern margins brilliant moonlight at times dispels the darkness of the sunless days. At that season, also, the aurora reaches its maximum brillance. At times, on crystal-clear nights, the whole sky is covered with surging waves of color; bands of green and blue and purple and pink go shooting, rolling, twisting across the heavens in a display of changing brightness never the same for two successive seconds. Only in the high latitudes can one find such superb celestial beauty.

Resources. The known resources are based on the natural vegetation. The tundra is the land of the reindeer and the musk ox and, during the warm season, the home of myriad birds and insects. The bordering seas are the habitat of seal, walrus, whale, and many kinds of fish. The human economy is based upon the utilization of animal life, because no tillage agriculture is possible.

With the passing of the winter snows, vegetation surges into life as though to make the most of the short summer season. Where the snow cover serves as a protecting blanket against intense cold, the vegetation is fairly profuse, while windswept places support but sparse growths. In swampy areas, caused by frozen subsoil and inadequate surface drainage, water-saturated spongy mosses abound; in the drier places, various kinds of lichens and reindeer moss cover the ground and even grow on the surfaces of naked rock. In some of the more sheltered and better drained lowland areas occur the arctic "prairies," consisting of herbaceous vegetation of biennials and of scattered grasses and shrubs usually less than knee-high. During the brief summers these "prairies" form oasislike spots where brilliantly colored flowers abound.

The drier parts of the tundra are capable of serving as grazing grounds for large numbers of meat animals, such as the reindeer, the caribou, and the musk ox.

Human activities. The human population of the tundras is sparse. These regions are at the poleward limits of the higher forms of life, and the struggle for existence is intense and hazardous. The native people include such groups as Eskimos of North America and the Lapps, Samoyeds, Yukaghir, and Chukchi of Eurasia.

A surprisingly varied set of cultures has been developed by the native peoples from the rather uniform environment of the various tundra areas. Although animal products are everywhere the principal source of food, the Eskimos are hunters and fishers, depending upon caribou and sea animals (Illus. A, p. 272); the Tierra del Fuegians are more primitive hunters and fishers; the Lapps and Samoyeds of northern Europe are dairymen, using domesticated reindeer; while the tribes of northern Siberia are herdsmen, raising great herds of semi-domesticated reindeer for meat rather than milk. In like manner the snow, stone, or sod igloo of the Eskimo is radically different from the large skin house of the northern Asiatics or the crude windbreaks of the Fuegians. In land transportation the Eskimos use dog sleds; the Fuegians, their own

Courtesy American Museum of Natural History N Y

(A) Eskimo woman fishing through the ice. Model in American Museum of Natural History

backs, the Lapps, reindeer-drawn sleighs (Illus. below); and the Siberians, reindeer back-packing. Even the sternest environment offers man numerous choices, of which he avails himself according to his traditional background and his inventiveness

Dependence upon the resources of the sea varies widely. Most of the inhabitants of Eurasia are inland dwellers; in the autumn they withdraw to the forest, where they can find shelter to protect their herds from the blizzards. There they also add berries and nuts to their diet of meat. Their mainstay of economic life, the domesticated reindeer, can use the tundra forage and provide its owners with materials for food, clothing, and shelter. The Lapps and the Siberian peoples of the tundra are nomadic; they live in tents throughout the year, only a few tribes having more permanent habitations. Their migrations and mode of life are adjusted to the requirements of their herds, and these in turn are in accord with the nature of the country. Since the most extensive pastures, those of reindeer moss, grow slowly and require several years to recover from overgrazing, the herds must continually be kept moving In winter these peoples migrate southward, in summer northward, seasonally seeking the areas where forage is most readily accessible and, so far as possible, avoiding winter coastal storms and summer insect enemies.

The Eskimos, generally coastal dwellers, depend more directly upon the sea They have become skillful hunters and fishermen

Photo by Mrs Waldheim

(B.) Wales reindeer team

They are recognized as being among the most adept people in the world in handling their skin-covered, decked canoes or kayaks. In west Greenland the Eskimos have become distinctly sedentary, but in the northern part of Canada most of them retain their nomadic tendencies. There in winter they concentrate in larger settlements, while for the summer caribou hunting they disperse over wide areas.

Western civilization is represented in the tundra chiefly at "gateway" settlements such as Churchill, Canada, and Murmansk and Dickson Island, U. S. S. R.

Courtesy Loman Bros, Nome, Alaska

A group of grazing reindeer in northern Alaska

Economic significance of the tundra. Although not equaling the subpolar regions, the tundra has long been of some importance as a source of fine furs. Thousands of sable and blue-fox furs are marketed every year from these areas of Canada and Siberia. It is said that because of his contacts with American fur traders the Eskimo thinks of the white man's world as one of big boats, soap, warm water, and odd-looking footgear, and that white men spend almost all their time looking for skins. So long has he trapped and brought his pelts in for trade, and so long has he been exhorted to hurry back with more, that he has come to think of the arctic skins as a sort of hub around which the wheel of civilization moves.

As a resource subject to exploitation in the distant future, the tundra pasture land must be given high rank. Areas of considerable extent are available for reindeer grazing. Since these animals survive without feeding or prepared shelter, the production costs are low. While there is little prospect of the industry becoming of great commercial significance in the near future, it has promise as a possible eventual source of meat, as the human population of the world has been increasing at a rapid rate and the pressure upon the land to produce the necessities of life is continually becoming greater. If these trends continue, it is inevitable that eventually cultivable lands must be used for crop agriculture and that grazing lands will become of increasing importance for meat animals. In that distant future the tundra regions may become recognized as the world's most extensive pasture lands (Illus. at left).

The Ice-Cap Type of Climate

In the ice-cap type of climate, all-year cold reigns supreme. The average temperature of the warmest month is below 32°F. Statistical data concerning climatic details are fragmentary, because no permanent meteorological stations have been established in these climatically hostile regions.

The ice-cap climate dominates interior Greenland, the Arctic Ocean, and Antarctica. These regions long have challenged the imagination and adventurous spirit of man. Associated with them are the names of a host of men fearless of the hazards of the unknown. Among those whose exploits have been truly heroic are Franklin, Greely, Nordenskjöld, Nansen, Scott, Shackleton, Peary, Amundsen, Wilkins, Papanin, Steffanson, and Byrd. Many other names merit a place in any honor list, but the above-mentioned are outstanding.

The question is often raised as to why

men face the hardships and dangers of polar exploration. The ice-cap regions are cold, hostile deserts: there is virtually neither plant nor animal life except along the margins. While lands for settlement cannot be expected as a reward for new discoveries and explorations in the polar regions, and perhaps other economic rewards likewise are remote, any explorations are justified that push back the veil of ignorance. Man seeks to know all parts of the world regardless of economic benefits. The ideal that knowledge is worth while for its own sake has been dominant in nearly all polar expeditions. Since aviation has become a practical means of trade and transportation, interest in the north polar areas has loomed large because of their location in respect to potential air routes, and thus has been added an economic motive to the zeal of explorers. But the lure of the unknown and the special fascinations of polar landscapes have been dominant incentives of individual explorers.

In recent years, scientific thought has been directed to the polar regions because of their possible influence upon world weather. Many scientists believe that if we knew more about the meteorological conditions in polar areas we would have added evidence upon which to interpret the weather of the middle latitudes. It is thought that a knowledge of the sequences of weather conditions over the polar ice caps might afford a fairly reliable basis for making seasonal forecasts regarding the weather which would be likely to prevail during the succeeding weeks or months over the agricultural lands within the intermediate climates. These are some of the problems which await solution, and it is possible that further knowledge of conditions within the polar regions will be of practical value. In view of the varied interests of adventure, of air navigation, and of meteorological research, the polar regions bid fair to remain in the limelight of exploration for years to come. The poles have been reached, but vast areas still unseen or seen only cursorily serve as a challenge to the zeal to know, a zeal which constitutes one of the finest attributes of man.

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Chapter Seventeen

THE ECONOMIC SIGNIFICANCE OF THE SEA

WITHIN THE EXTENSIVE WATERS OF the sea are bountiful resources of food, raw materials, and other products useful and valuable to man. Some of these resources, such as those of the fisheries, have long been utilized, at least partially, but others of potential value have only recently been examined or exploited. Realization of the sea as a storehouse of wealth can add to our food and raw-material resources. Similarly, while more energy is contained in the movements of the tides, currents, and waves than is now utilized in all of man's industrial plants, at present the amount of power taken from the sea by man is negligible. But there are indications that the technical difficulties of harnessing some of this power can be overcome in the near future.

That new resources of the sea are available is strikingly illustrated by the recent extraction of minerals. Until the present century there was almost no direct exploitation of the minerals contained in sea water ✓except of salt. Since the 1930's, however, with the increasing demand for some of the minerals of the sea and the development of new methods of handling large quantities of sea water, bromine and magnesium have been recovered in large quantities. The construction of the first bromine plant using sea water as the source of raw material was begun in the United States in 1934. With the tremendous increase in demand for magnesium just before and during World War II, several plants were built to extract this metal from the sea. Of the 240,000 tons of magnesium produced in the United States in 1943 (compared with 2,400 tons in 1938), about one-third was from the sea.

The value of the sea cannot be measured alone by resources such as fishery products and minerals, nor even by its potential role as a source of energy. Throughout geological ages the seas have aided in the construction of vast areas of sedimentary rocks, areas which after uplift and surface changes now constitute large parts of the continents. Interbedded with these sedimentary rocks are great stores of coal and petroleum—products without which the modern industrial civilization would not be possible.

The climatic influence of the sea is another factor to which the yardstick of pecuniary value cannot be applied. The seas serve as a vast primary reservoir from which the air derives the supply of moisture which is essential to life on the continents. They serve also as a great regulator of temperature by absorbing heat, and thus exerting a cooling influence on the air above, or by radiating heat and thus warming the air.

Another economic role of the sea, the value of which can hardly be expressed in monetary terms, is its use as a highway of transportation. The ocean is a roadbed against which there are no charges for construction, maintenance, or taxes. Open to most nations and touching all shores, it has always appealed to the adventurous spirit of man, has induced exploration, and has facilitated international trade.

The most important direct use of the sea today, as in the past, lies in its ability to provide food. Fishing is often quoted as man's oldest industry. Certainly, from prehistoric days on, the sea has furnished a substantial part of his food. To millions of people in the tropics, particularly to those in the rice-consuming countries of the Far East, fish rather than meat provides the necessary proteins in the diet. Along many of the rugged coasts of western Europe, where but little land is fit for agriculture, fishing is the principal industry, this being especially noteworthy in the case of Norway, Brittany, and northern Scotland. England, deficient in products of the farm, secures a catch which provides for an average annual consumption of about 40 pounds of fish per capita.

Americans eat less fish than do most Europeans. As an adjunct to the regular meat diet, however, the value of fish is greater than is indicated by its measure in dollars and cents. Products of the sea are rich in essential mineral salts, and especially so in vitamin D and iodine, and thus they serve a useful purpose in providing a varied and wholesome diet.

The nature of marine life. As a result of diverse environmental features, some parts of the land areas of the world support abundant plant and animal life, whereas in other parts such life is sparse. The oceans similarly provide diverse environments, although the contrasts are not so great as on land. The old adage that the seas are barren wastes has of course but a small element of truth. Conversely, the more recent saying that the sea is a rolling meadow, teeming with life, is equally absurd. Broadly speaking, the ocean as well as the land has its rich pastures and its barren deserts. In the sea, as on the land, are flora and fauna of widely varied kinds. There are microorganisms and macroorganisms belonging to the plant and animal kingdoms, and of each there are numerous species.

Plankton. The basic food supply of living organisms in the ocean consists of *phytoplankton*, the collective name for simple-structured plants which convert inorganic matter into the organic matter of their bodies. Associated with these minute plants are plankton animals, the *zoöplankton* which feed upon the plants. These plants and animals, many of them microscopic in size, together with eggs and larval forms of larger animals, passively float and drift, forming in some sea areas fabulously rich assemblages of marine life.

The productivity of plankton is affected by many factors of which light, ocean currents, vertical mixing, and chemical content of sea water are recognized as important and interrelated. Since sunlight is the source of energy for the photosynthesis performed by the phytoplankton, these plants are confined to depths of less than 600 feet, where light can penetrate. Surface currents and vertical mixing are important factors in the presence of plankton as they help provide nutrient salts necessary for plankton development. Nitrates and phosphates are among the nutrient salts necessary to the favorable development of plankton.

The rate of growth and reproduction of plankton, other things being equal, seems to be accelerated along coasts where rivers pour in nutritive salts, and where opposing currents lead to the upwelling of large quantities of salts which would otherwise remain at greater depth. Thus, the contact zone between warm and cold currents, especially on or near continental shelves (see page 278, and Physical Map of the World), are particularly productive of planktonic life. This is the case off Japan, where offshoots from the warm Japan Current (Kuroshio) and the cold Oyashio intermingle and on the Newfoundland banks where the warm Gulf Stream and the cold Labrador Current impinge upon one another.

Plankton is very unevenly distributed throughout the oceans. In general, it is probable that plankton is more plentiful in the middle and subpolar latitudes than in the tropics, although further study is necessary before this can be stated conclusively. It is clear, however, that among the richest pastures of plankton are those of the cooler waters bathing the shores of eastern North America and western Europe, whereas the centers of the great oceans are relatively bare of plankton.

Many species of fish feed directly on plankton, whereas other fish live on smaller fish which, in turn, feed on plankton. Herring and sardines belong to plankton-feeding fish. Whales, the world's largest mammals, feed upon a special plankton called "krill" to build up their huge bodies.[1] Such fast-swimming fish as tunas and salmon, on the other hand, prey upon other fish. But directly or indirectly, all fish are dependent upon plankton, and it is no accident that the richest fishing grounds of the world are areas productive of plankton.

Courtesy U S Bureau of Fisheries

Catching fish with a purse seine off the Alaskan coast

Fish and man. The degree of popularity which fish have attained in the diet of man has depended upon the ease with which they can be procured and the relative scarcity and abundance of other foods. People inhabiting rugged littoral lands such as Brittany and Norway have long been proficient in testing the larder of the sea. The peoples inhabiting subpolar and polar areas where land life is not abundant must depend largely upon life of the waters for their sustenance. Again, where the ratio of land per capita of population is small, as in Japan, the seas assume an importance vital to the life of millions of people.

Methods of fish capture. Successful fishing depends not only upon an abundance of fish, but also upon the ingenuity of man in using instruments of capture. The four main devices widely used are spears, traps, nets, and hook and line. Spearing fish is a rather primitive method which still is extensively practiced in both tropical and polar regions. Traps, including pound nets and weirs, are used in shallow waters in many parts of the world and in some areas account for a considerable part of the catch. The bulk of the commercial fish is secured by means of hooks and lines, and by various forms of nets such as trawls, seines, and drift nets.

The particular method used depends on the habits and the habitat of the fish sought. Pelagic fish, living near the surface of the water, are caught largely by drift nets and seines. Drift nets, which are used in many different lengths, are attached to slowly moving ships or floating buoys and kept vertical by means of weights placed along the bottom edge. The mesh is of such size that the fish is able to push its head through, but not its body; the gill covers are caught and the fish can neither pull his head back nor pull his body through the net. Herring, mackerel, and pilchards are among the fish caught by this method. Seines are of many varieties and designs, but most of them consist of a large net which is used to surround a school of fish. Gradually the ends of the net are drawn closer together, until a large number of fish are caught and may be removed either by hand or by lifting the net and its catch out of the water (Illus. p. 277). This method may be carried out partly on land and partly on the water, or entirely in the water with the aid of small boats.

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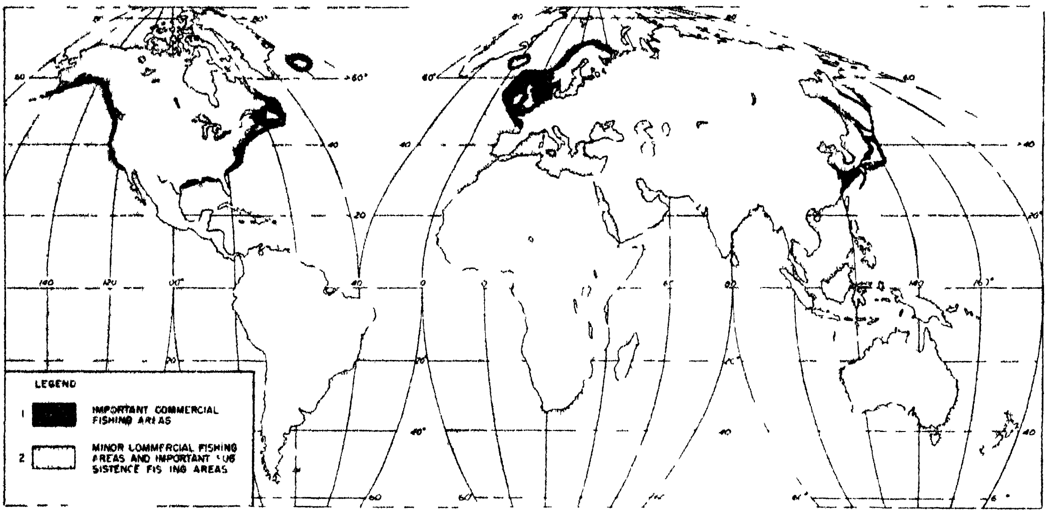
[1] Observation has established with reasonable certainty the belief that whales spend the breeding season in the more temperate and warmer waters. In these waters the mammal becomes lean and gaunt because of the dearth of planktonic life. Once he returns to the abundant "krill" of the polar seas, his parts readily become rounded.

Demersal fish which live near the sea bottom of the continental shelves, usually at depths of 200 feet or more, were formerly caught by liners, extended ropes from which small lengths of cord and baited hook were attached at regular intervals. In places where the sea bottom is irregular this system is still in vogue, but the modern trawl, a large net of flattened conical shape, in some cases as much as a hundred feet long, is the more popular gear for demersal fishing. This huge bag is dragged slowly along the sea bottom by powered vessels. The trawl does well where the sea bottom is smooth, but it cannot be used successfully where the bottom is rugged or rough.

The capture of fish on the high seas has been encouraged since the early 1930's by the development of modern, highly mechanized factory, or mother, ships. These ships with their auxiliary boats form highly mobile and versatile units which can follow schools of fish for long distances. They have been used in the salmon and crab fisheries of the Pacific, for canning, and in the tuna fishery, for freezing.


LEGEND
1 ■ IMPORTANT COMMERCIAL FISHING AREAS
2 □ MINOR COMMERCIAL FISHING AREAS AND IMPORTANT SUBSISTENCE FISHING AREAS

Principal fishing areas of the world

The major fishing areas. The four leading fishing areas of the world are: (1) the seas bordering central and northern Japan and eastern China, Korea, and the Soviet Union in the northwest Pacific; (2) the great fishing banks of the Atlantic off the coast of Newfoundland and New England and the shallow coastal waters south along the east coast of the United States; (3) the extensive shallow waters off the coast of northwest Europe; and (4) the Pacific coast of North America from Alaska to California (Illus. above). Each of these areas supports large fishing fleets and has fishing industries employing thousands of people. From each the catch serves as an important food supply and provides a commodity of great commercial value.

THE NORTHWEST PACIFIC. Of the large prewar powers, Japan was most directly dependent upon the sea. The total land area of Japan proper is about 147,000 square miles, or less than that of the state of California. Because of ruggedness throughout most of the area and unfavorable climate in some parts, only 16 per cent of the land is cultivated. Since the total population is approximately 78,000,000, there is an average of more than 3,000 persons for every square mile of land cultivated.

Photo by Espenshade

Catch of sardines landed at Komogawa Fish Market

Japan, however, as an island nation in the midst of a prolific sea area, occupies a strategic position for fishing. The mixing of the warm waters of the Kuroshio and the cold waters of the Oyashio favors the sustenance of abundant marine life in the numerous inter-island straits and seas, and although the continental shelf surrounding Japan itself is narrow, near by are the extensive areas of shallow water which border the Asiatic mainland (Illus. p. 278).

In prewar years, the total quantity of marine products from fishing operations based on Japan proper far exceeded that of other countries and accounted for about 20-25 per cent of the world's total. During the period 1931-1938, these fisheries had an annual production which varied from 7.7 billion pounds to 10 billion pounds.[2] The fisheries engaged more than 350,000 boats and about 1,500,000 people, full or part time.

Japanese fishing was largely concentrated in the coastal waters of Japan, the Pacific waters east of the islands, and in the near-by Yellow and China seas, along the coasts of Korea and Karafuto and around the margins of the Okhotsk Sea, although its fleets operated in many other parts of the world. In the northern waters herring, cod, salmon, and crab were among the important species taken, whereas farther south, sardines, bonito, tuna, mackerel, and yellowtail accounted for large catches. Shellfish, crustaceans, molluscs, and seaweed also constituted part of the Japanese production (Illus. p. 279).

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[2] This includes only the fishing based upon Japan proper If former empire areas are included, Japan's production amounted to 30-35 per cent of the world's total and ranged from 10 7 to 15.2 billion pounds in the period 1931-1938.

Fishery products form an important part of the Japanese diet and the people have few fish prejudices. Markets in Tokyo and other Japanese cities offer such delectables as octopi, squid, sea urchin, seaweed, and whale meat in addition to the types of seafood considered palatable by Americans.

That the sea is a generous provider to these islanders is illustrated by a practice very common in the seaside towns along the coast. When the tide ebbs, many of the poor men, women, and children flock to the shores with sticks and vessels. Every object with a spark of life, particularly shellfish and crabs, and also bits of seaweeds, are gathered.

In the light of these facts it is not surprising that Japan should have evolved a folklore and religion in which fish play a part. Among the seven deities worshiped by most Japanese and particularly remembered at New Year's is Ebisu, the deity of the fishermen who carries a fish under one arm and holds a fishing pole in the other hand. Dried bonito sticks are presented to friends as tokens of congratulation on such occasions as the birth of a child, a marriage, or success of any kind, and a fish symbol is used on the boys' festival day celebrated each year.

While still one of the world's leading fishing nations, as a result of its defeat in the recent war Japan lost some of the grounds formerly utilized by its fishermen. The rich salmon-crab area of the north, and part of the trawling grounds to the west, are now closed to the Japanese.

Although Japan formerly dominated the fishing of the Northwest Pacific, the Soviet Union, Korea, and China are important producers in the waters bordering their coasts. Some of the fisheries formerly worked by Japan may serve to increase their catches in the future.

The Atlantic Fisheries of the United States and Canada. The development of colonial America was aided greatly by the wealth of fish found in the shoal waters of the North Atlantic. Colonial New Englanders were confronted at the outset with the difficulties of preparing the forest-clad and boulder-strewn land for tillage. Agriculture in most places involved much labor and brought small returns. With an abundance of timber available, the settlers soon mastered the art of building fishing smacks by which the sea was made to supplement the food supply wrung so laboriously from the land.

The banks off the coast of New England and Newfoundland constitute the major part of another of the four principal fishing grounds of the world. They extend from Nantucket to the eastern coast of Newfoundland, a distance of about 1,100 miles, varying in width from 50 to 250 miles. (See Map, page 278.) The more important are: the Grand Banks, southeast of Newfoundland, with an area of 37,000 square miles; the Sable Island Bank, southeast of Nova Scotia, with an area of 7,000 square miles; and the Georges Bank, immediately east of Cape Cod, with an area of 8,500 square miles. As a whole, they are the foremost cod and haddock grounds of the world. Great numbers of American, Canadian, British, French, and Portuguese fishing vessels frequent them regularly. Although cod and haddock are the major species caught, herring, mackerel, flounder, and other species are also taken.

Menhaden, a migratory fish caught from Maine to Florida, is of major economic importance, leading by volume in 1946 all other species in the United States catch. The greatest quantities are secured in the waters bordering the Mid-Atlantic states, Virginia and North Carolina. Since the meat is relatively unpalatable because of its high oil content, it is not in demand as food but provides oil and meal. The oil is extracted for use in the manufacture of soap and paints and the meal, produced in the same operation, is used as a fertilizer and an ingredient in animal and poultry feeds.

Fisheries of Northwest Europe. The people inhabiting the coastal areas of northwest Europe have engaged in ocean fishing since early historic times. Not, however, until about A.D. 1400, after the Hollanders had devised improved methods of curing herring, did the fishing industry become of commercial importance. The location of Holland on the North Sea and on the Rhine made it easy for the Dutch to procure fish, especially herring, and, after curing them, to sell them to the people of neighboring countries. This export trade eventually extended so far southward as to include even the Mediterranean lands. So profitable was this traffic and the trade in other products which developed in connection with it that it gave rise to the well-known adage, "The city of Amsterdam was founded on the bones of herring." The renowned Dutch navy of the seventeenth century and the extensive trade of the Netherlands were merely children grown to maturity in an environment which stimulated their development. The vast colonial possessions of the Netherlands can be considered an indirect heritage from the North Sea fisheries.

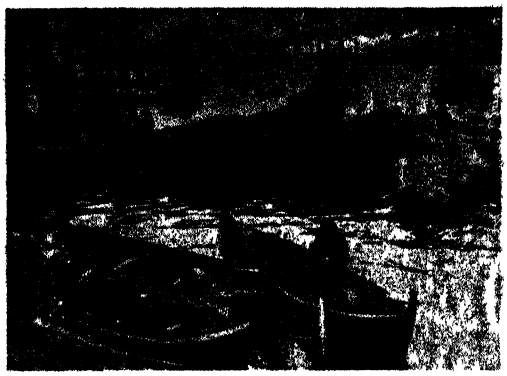
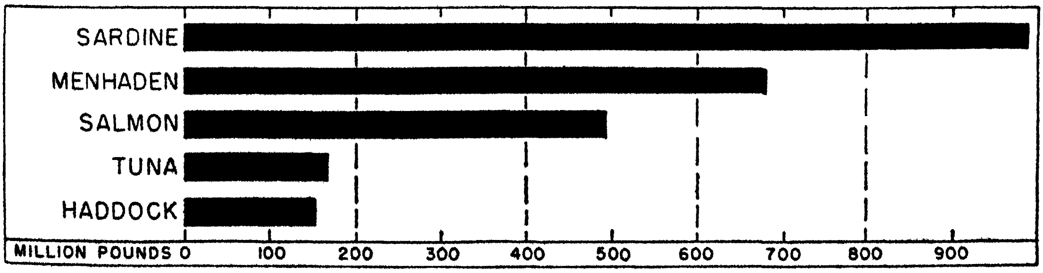


Photo by N. A. B.

(A.) Hammerfest, Norway. Lapps in the small boats in foreground engaged in fishing for subsistence purposes. Larger boats belong to the commercial fleet.

England, too, adjoins the North Sea. While despotic kings thwarted for centuries the development of the fishing industry, when this restraint was removed the British fisheries soon exceeded those of the Netherlands. The continental shelf, of which the British Isles are an exposed portion, is unusually wide off the western European coast and includes practically all of the North Sea as far as the Shetland Islands. (See Physical Map of the World.) These shallow waters, extending from the Bay of Biscay to beyond the Lofoten Islands off the Norwegian coast, together with those around Iceland, have given rise to some of the most intensive fisheries of the world. Collectively the production of the United Kingdom, Norway, the Netherlands, Belgium, Denmark, Sweden, Germany, France, and Iceland averaged about 8.5 billion pounds in the prewar period.

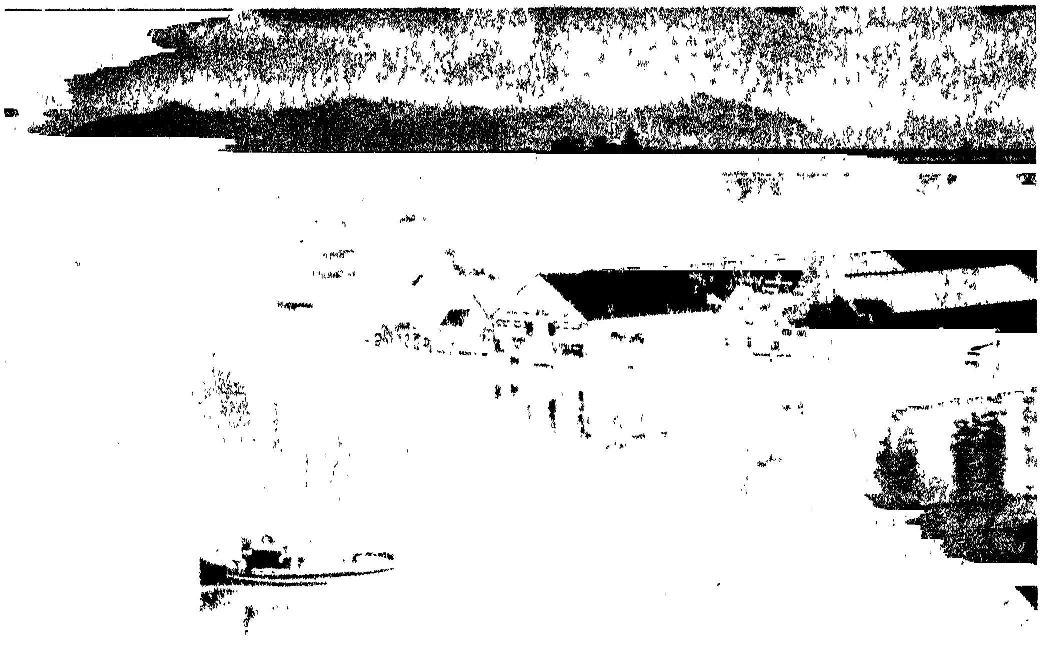
The principal fishing grounds are found in the North Sea, the Dogger Bank and the Great Fisher Bank being the most important producing areas (Illus. p. 278). These waters are unusually rich in plankton, owing to the combined effects of sev-



(B.) Production of salmon and tuna fisheries of U. S. A. since 1930.

eral factors: (1) the shallowness of the North Sea; (2) the vertical circulation caused by the slow cooling of the waters of a branch of the Gulf Stream Drift which enters the North Sea between the Shetland and the Orkney Islands; and (3) the intensive mixing which results from strong tidal currents, the entrance of waters of low salinity from the Baltic, and the entrance of fresh waters from many rivers. Pelagic fish, such as herring and mackerel, wax fat on this plentiful plankton diet. The herring in turn are pursued by hungry cod, haddock, shark, and dogfish.

Grimsby, England, is one of the world's greatest fishing ports, perhaps the greatest in the variety and value of fish landed. Other fishing centers of importance on the North Sea are Yarmouth, Hull, Aberdeen, and Bergen. Billingsgate, on the Thames in London, is the most famous fish market in the world.



Courtesy U S Bureau of Fisheries

One of the numerous salmon canneries on the coast of Alaska

Northeast Pacific Fisheries. A fourth great area of production is the west coast of North America from Alaska to California, which has high rank chiefly because of salmon, pilchard, and tuna fisheries, although halibut and other species are taken in sizable quantities (Illus. pp. 278; B, 281).

Salmon, with an annual pack averaging 388 million pounds in the period 1936-1945 and valued at 55 to 70 million dollars annually, has long dominated these fisheries shared by the United States (including Alaska) and Canada.

The life habits of salmon render them easy prey to large-scale methods of fishing As fingerlings they leave their first habitat of mountain lakes and streams and proceed downstream to the sea. After about three years they return for spawning in the fresh waters of their nativity. These returning hordes of salmon going up some of the major streams can readily be caught by machine methods The catch is efficiently handled by the numerous canneries which have been established along the inlets and lower stream courses from Alaska to Oregon (Illus. p. 282).

In many places the activities of man have jeopardized the life of the salmon. Some of the coastal streams of our Pacific states have been diverted for irrigation purposes, and in some, high dams have been constructed for the development of electrical power. In either case the return of the salmon to their upstream habitats has been made more difficult. Lumbering activities have frequently choked the streams, and in such instances, likewise, the return of the salmon has been rendered nearly, if not completely, impossible. Furthermore, the reckless catching of all fish possible, without regard to effect on spawning and reproduction, has led to serious depletion of supply. Small salmon runs have awakened the respective governments to the dangers of continued depletion, and by international agreement conservation measures have been instituted to protect the salmon from ruthless and destructive exploitation.

California, the foremost fish-canning state, had a fish pack valued at more than 50 million dollars, of which sardines (pilchards) and tuna constituted the major part. Pilchards are plentiful in winter, whereas tuna are taken in greatest quantities in off-shore waters during the summer months. Therefore, many firms have found it advantageous to can both kinds, keeping their plants in operation throughout most of the year.

The deeper water on and beyond the continental shelf off Alaska and British Columbia contain the best halibut-fishing grounds of the world. These fisheries were carried on so vigorously in the past that their productivity declined. With international regulation since 1930, however, they have revived, and in 1946 production passed 60 million pounds for the first time since 1917.

Tropical fisheries. When a jet-black head splits a wave in the Polynesian waters and a Tahitian boy emerges with a squirming miniature devilfish, what is the figure that shall be entered on the world ledgers of values? Millions of tropical people sustain themselves by the wealth of marine life that teems in the waters about them. To estimate the amount or values of such catches is impossible.

The tropics contain no great commercial fisheries. This is due in part to the lack of great populations to produce heavy demand for marine foods. It is also possible that warm seas do not support as much plankton as do those of higher latitudes. Tropical fish seem to be characterized by more species but less numbers of any one species than is true of fish of cooler waters. From the standpoint of commercial exploitation, this is a disadvantage. It is held by some that tropical and subtropical fish are soft and not as palatable as fish of colder waters. While this may be true of certain species, many others are fully equal in texture and flavor to the popular fish of the northern seas.

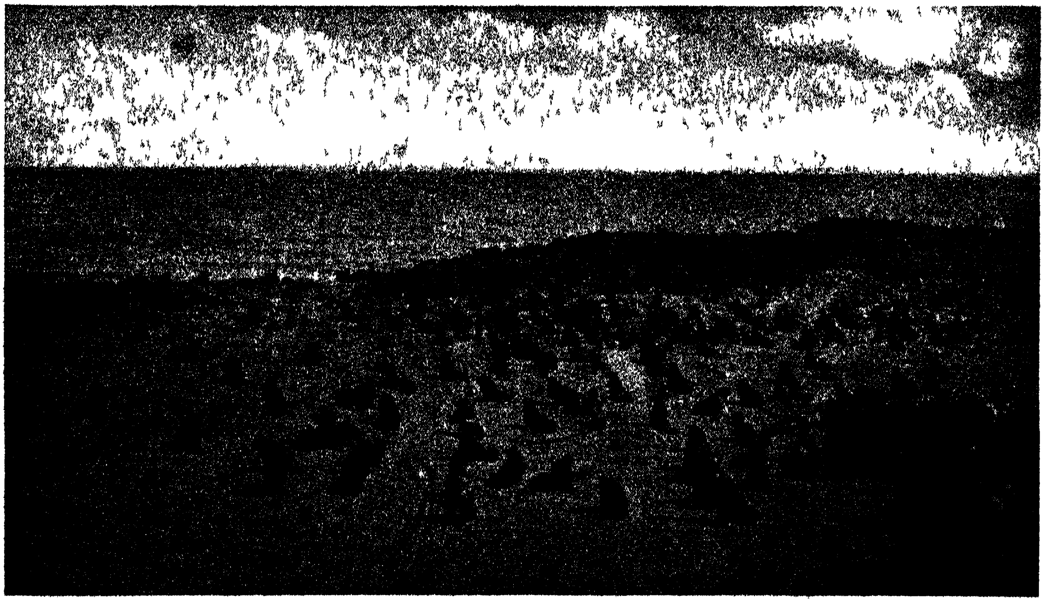
The fish resources of lower latitudes have not been greatly exploited because of their distances from large market centers, difficulties incident to the preservation of fish in warm climates and competition with a rather plentiful supply in northern waters. A population faced with a problem of greater food economy, or one seeking greater varieties of palatable foods, would readily overcome these difficulties.

The whaling industry. Although whales have attracted attention ever since man began to sail the seas, for centuries the animal was considered chiefly as a curiosity and a fit subject for tall stories. Eventually whale oil, derived from the thick coat of blubber which protects this warm-blooded animal from the coldness of the water, was found to be well adapted for use in lamps. The demand thus aroused initiated the hunt for the whale. Small shore boats were launched in charge of courageous men equipped with simple lances and spears. At first casualties were more often on the side of man than on that of the whale, but the prizes were such as to be highly profitable for those who survived.

During the nineteenth and early twentieth centuries the Norwegians, British, and Americans prosecuted the industry vigorously and persistently. In all the oceans of the world the whale has been pursued to the point of extermination, except in the distant Antarctic waters, the ice-fringed "bottom of the world," which remains as the last haven of refuge for this largest of mammals. Here the British, Norwegians, Germans, and Japanese have been the major participants in whaling since 1930.

The whale hunt of the Southern latitudes is a modern industry with techniques considerably advanced over those of the nineteenth century when the American whalers were in their heyday. An Antarctic whaling expedition of today consists of a factory vessel accompanied by several high-powered catcher boats each equipped with harpoon guns Aboard the factory ship the whales are processed into oil, meal, meat, and other products, oil generally being the major and most valuable product. Hydrogenated whale oil is used in margarine and other grades are used in the manufacture of soap, glycerine, varnishes, glue, and other products.

Efficient modern whaling methods which can achieve large catches within relatively short periods of time have made it imperative to regulate catches so that whaling can remain a profitable industry. Since the 1930's whaling has been regulated internationally, although prior to the war Japan, one of the whaling nations, was not a party to the conventions.



Courtesy U S Bureau of Fisheries Photo by H J Christoffers

Part of the seal herd on one of the Pribilof Islands

Fur seals. Seals also are marine resources which have great economic significance, the Pribilof Islands off the coast of Alaska being the chief center of the fur-seal industry. There, each year, many thousands of seals gather from distant waters and remain for a few months while the young, known as *pups*, are born and grow large enough to swim into the ocean with their mothers. When the migration is on, the males reach the rookeries first. Later, by a few days or weeks, when the females arrive, the males engage in fierce combat for their possession. The size of the harem assembled varies from five to fifty, depending largely upon the pugilistic ability of the males. The cows soon give birth to single pups, the numbers of each sex being about equal. Since the harem system prevails, an excess of males soon accumulates

These bachelors, as they are called, are not permitted by the "harem master" to disport themselves in the immediate vicinity of the breeding grounds. Hence they assemble on what is termed "hauling grounds" (Illus. p. 284). It is from among these bachelors that the United States government officials select animals for killing. This practice supports a flourishing industry and at the same time provides for an increasing seal population.

The story of the seal industry is one of exploitation, depletion, and then conservation. It is a story of wanton destruction which occurred chiefly during the nineteenth century. Before the slaughter began, the seal population of the Arctic and Antarctic waters was estimated to be in excess of 10,000,000. Before the close of the century, the Antarctic grounds ceased to be of commercial importance. The number of seals in the Arctic waters was reduced to a few hundred thousand or confined almost exclusively to the American-owned Pribilof Islands. Although the government at the close of the nineteenth century was putting forth strenuous efforts to conserve the seal herd, it was confronted with a difficulty arising from the peculiar habit of the seal to spend the greater part of the year in the high seas. Here pelagic sealing was prosecuted with vigor by Japanese, Russian, English, and American ships.

The United States government, however, persisted in its treaty-making attempts, and an agreement was signed in 1911 by the United States, Great Britain, Russia, and Japan which prohibited pelagic sealing. In 1912 the size of the Pribilof Islands' seal herd was about 216,000; by sound conservation and management practices the herd has now increased to more than 3,600,000. Although Japan abrogated the treaty in 1942, the herd is still protected under a provisional agreement signed by Canada and the United States in 1942. The total "take" during the 1947 season was 64,523 skins, and the 1947 fall auction, one of two held annually, yielded gross proceeds to the United States government of more than $1,470,000.

Other marine products. Many other products, of varying significance, are or may be derived from the sea. Among the more outstanding ones the following deserve mention: salt, obtained from sea water; iodine and potash, derived from seaweeds; leather, from the hides of marine animals; agar-agar; pearls; corals; oysters; clams; shrimps; crabs; lobsters; and sponges. The total value of all these major and minor products of the seas and oceans of the world cannot be computed with any high degree of accuracy. Nevertheless, it is evident that the direct economic importance of the ocean as a provider of foods and raw materials is tremendous.

The future of the fisheries. The future may bring expansion of fisheries production. This may be accomplished in three ways: (1) extension of operations to areas which at present are only partially utilized, such as the seas of the coasts of Uruguay and Argentina, or certain areas off the west coast of Africa; (2) more intensive use of present important fishing regions, in many cases by utilizing new species; and (3) greater use of the catch by eliminating much of the waste which occurs under present methods through spoilage or the throwing back of edible but not desired species. But accompanying new production will also be problems of conservation, the need for which has already been felt in many of the important fisheries of the world.

The wealth of the sea is large, but it is not inexhaustible. With modern fishing gear such as mechanized trawlers, large purse seines, harpoon guns, and factory ships, diminishing catches have been unmistakable in some fisheries. Conservation can in some cases be achieved by individual nations, but because of the international nature of most fisheries joint action by various nations is necessary for the solution of larger problems connected with the preservation of sea resources.

Some noteworthy achievements have been made toward conservation through international regulation. A successful example is that of the International Commission for the conservation of the halibut fishery of the Pacific. In Europe, where many nations are engaged in fishing, it has been possible to obtain agreement on uniform mesh regulations and size limitations for fish in the North Sea Conventions of 1936, 1943, and 1946. Many other fisheries, however, which show indications of reduced production, probably need regulation in order to achieve sustained yields. Better conservation of fishery resources of the sea is urgently needed, especially in the long-used fishing areas. Unfortunately the problems involved are extremely complex, and despite the intensive investigations that have been conducted in specific localities, our knowledge of the facts which are fundamental to sound management is still fragmentary.

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Chapter Eighteen

MINERAL RESOURCES ESSENTIAL TO INDUSTRIAL PROGRESS

In earlier chapters we have paid homage to the land as the home of man. Attention was called to differences in thought and attitude evoked by the term *land* as used by people under varied circumstances. In Iowa, the tendency is to think of land as fostering great fields of tall corn; in Arizona, people think of land in terms of mining, colorful and majestic scenery, or irrigation; and in New England, land is thought of as characterized by forested hills and rocky shores. The sons of the cattle ranchers of the Great Plains have a concept of the land in terms of grass, extended horizons, and great distances, whereas the sons of miners think of the land in terms of hidden stores of wealth obtainable through shafts and tunnels. Thus, while the term *land* may be defined as "the exposed surface of the lithosphere," its connotation to people who live under different environmental conditions varies widely. In some places land presents a barrier to be overcome, as, for instance, a ridge or mountain to be penetrated by a tunnel or laboriously crossed by winding trail or zigzag highway. Elsewhere, land is truly the Mother Earth, whence, through tillage and pastoral agriculture, food for sustenance will be produced.

Since the significance of the land in providing food supply is recognized as being supreme, several chapters in this book are devoted to the productivity of the land under different climatic conditions. However, an additional aspect must be recognized if we would view the subject more broadly, because land implies subsurface as well as surface characteristics. The *content* of the land in terms of minerals and rocks is important in relation to soil-building materials, power resources, and ores of industrial significance.

The content of the land. In a broad sense, the upper zone of the land, known as the soil, may be said "to have everything" because it is made up of mineral and organic materials teeming with life. Although loosely spoken and perhaps lacking in scientific precision, the common expression "the upper twelve inches of soil is the most densely inhabited zone on earth" represents truth vividly stated. The diversity of mineral content and the wealth of minute life forms make it so. Since this phase of the land is basic to agricultural productivity, it has been dealt with in connection with our discussion of climatic and agricultural regions.

As we move toward higher standards of living, there are, however, other aspects of the land that must be considered and that should be understood if we are to interpret with some degree of accuracy the progress of industry in relation to present problems.

These aspects refer to the mineral resources which provide the power and the means for harnessing it whereby man has become a *manager* of energy obtained from mineral sources rather than a *source* of energy to accomplish the manual labor of production. Whereas primitive man must depend on his own meager supply of energy to produce his food, shelter, and clothing, in the modern industrial world man does his work by directing the flow of energy from coal, petroleum, gas, and water power. It is only through efficient production that a high degree of prosperity may be attained, and efficiency is dependent on power harnessed by machinery and directed by human ingenuity. Thus, at the outset, let us see clearly the three great essentials for industrial progress and potentially high standards of living: (1) sources of energy available for conversion to power; (2) mineral resources, such as iron and copper, whereby power may be harnessed to do the work of production; and (3) directive genius for converting the raw materials into the finished commodities needed and enjoyed by man. The last named is usually termed the *human factor.* Availability of material resources is of little significance where man fails to do his part, but likewise the human factor is useless if the fundamental resources cannot be had. Over the earth man varies greatly in his ability to devise, invent, and direct industrial processes. Likewise the stores of available resources vary widely over the earth. The greatest progress has been made where man has shown inventive and industrial adeptness, and where power resources and industrial raw materials have been available. Since these occur irregularly over the earth rather than in large continuous areas or broadly banded zones, localized centers of industrialization and congested population have developed in connection with economic exploitation. Countries favored by numerous and varied centers of such resources, and where man has shown the needed initiative, have attained leadership in industrial and military strength. Let us therefore try to analyze more closely the basic phases of natural resources which appear to play such an important role in the world today.

Minerals and rocks as economic resources. The distinction between rock and mineral in a strict sense was clarified earlier in this treatment. (See Chapter Three, pp. 28-29.) We need now to be reminded that while the total number of known minerals is large, the number of high importance from a geographic point of view is small. They may be classified into three groups: (1) minerals great in importance because they make up most of the common rocks used in construction and likewise have direct relation to soil content and structure; (2) minerals important as such without complicated processes of manufacture; and (3) minerals which constitute raw materials for manufacture into products vital to industry. The metallic ores are the chief representatives of the latter group.

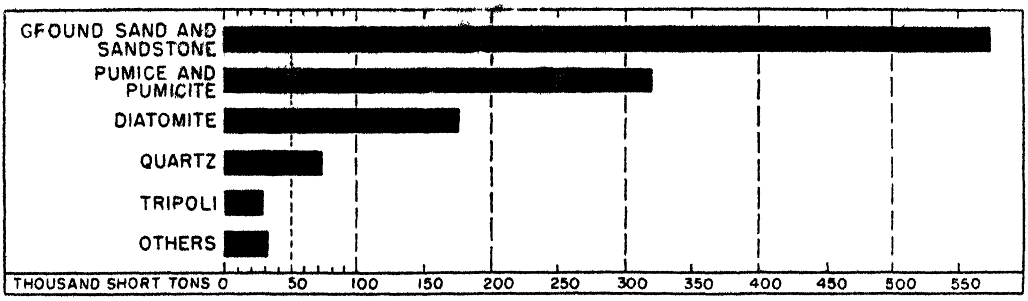
The minerals which are particularly significant as major constituents of the common rocks include quartz, feldspars, hornblendes, micas, calcite, and kaolin. Each of these has uses in the industrial arts also and is therefore of direct economic importance as well as being an important rock constituent. In this discussion we do not attempt to describe completely each mineral treated; only such phases are presented as have a direct bearing on the use made of the mineral.

Rock constituent minerals: QUARTZ. The most common kinds of quartz are known as milky, smoky, or rose quartz, quartz crystal, agate, jasper, amethyst, and opalized wood. Although they differ widely in appearance, they have the common quality of a degree of hardness (7) that usually scratches glass and they are relatively insoluble in water or weak acids. They all have as their essential chemical constituents silicon and oxygen in the ratio of 1 to 2 and are therefore designated by the symbol SiO_2. Because of contained impurities they may differ considerably in color and in physical properties such as crystallization. While quartz does not decay readily, it shatters under the influence of temperature changes; that is, it suffers *disintegration* rather than *decomposition.* Upon disintegration the resultant small particles are commonly known as "grains of sand." Although it is not the exclusive constituent of sand, it is generally the most common one.

In the soil, quartz serves its most useful purpose in providing body and friability. Because it tends to produce relatively open texture, it facilitates the ready movement of ground water and aeration, and thus the physical condition of the soil is made much more favorable for the penetration of plant roots and for cultivation than would otherwise be the case.

Natural abrasives are chiefly silica and as such give rise to widespread use of various forms of quartz. The terms by which these forms are known in the trade include tripoli, ground sand and sandstone, pumice, diatomite, and others. In the United States, the sales of crude quartz, including the mineral in crushed and ground form, ordinarily vary from 40,000 to 100,000 tons per year, and those of ground sand or sandstone average about 550,000 tons yearly. Illinois, New Jersey, Ohio, and Pennsylvania rank high in output of ground sand and sandstone, whereas the states bordering the Pacific lead in output of crushed and broken quartz. Massachusetts, Maine, and North Carolina likewise market sizable amounts of crushed or ground quartz annually. The importance of the abrasive industry in our economic life is emphasized by the fact that abrasives are used to grind and polish smooth surfaces in nearly all machinery where moving parts are involved. Without these finishing touches the machine age, with its recognized significance for efficient mass production, would be of little consequence. Quartz, as one of the most essential of the abrasives, thus has industrial importance of its own as well as importance as a rock constituent (see Illus. below).

Quartz owes its high importance as a building material to its being the principal constituent of sand. The sands used in plaster and concrete work must withstand the influences of the weather and lend themselves readily to induration by cement. These functions are effectively served by quartz sand.

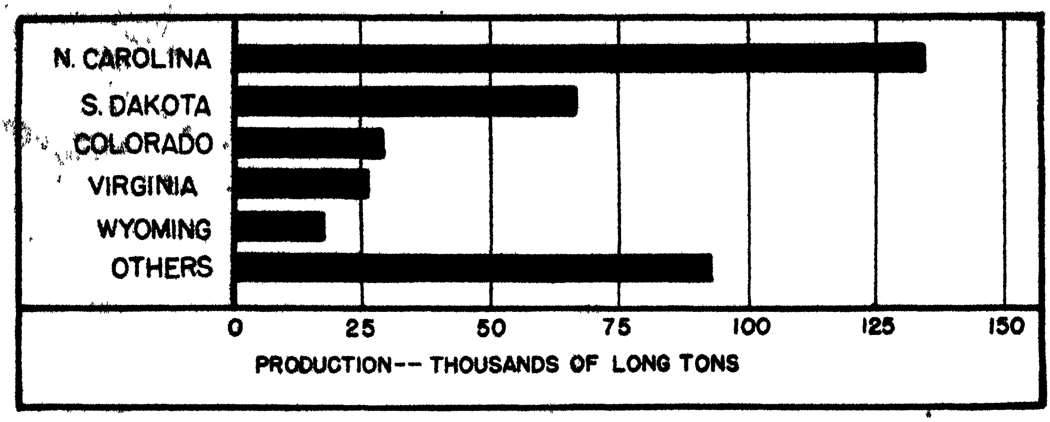


Natural abrasives produced in the United States in 1946. Silica is the principal constituent of each of the kinds shown. Quantities vary but proportions remain similar in different years.

FELDSPARS. The term *feldspar* has come to us almost unchanged from the German and means "rock of the field," thus indicating its common occurrence in some places. It should be thought of not as a single mineral but as the designation of a group of minerals which have similarity of chemical and physical properties.

The feldspars are quite brittle, have cleavage in two planes, and break with an uneven surface. Because of impurities they have different colors, usually varying from a light flesh color to brick red. They are not quite so hard as quartz.

As shown graphically in Illus. A, p. 290, North Carolina and South Dakota are the leading states in the mining of feldspar and are followed by Colorado, Virginia, and Wyoming. Usually feldspar is mined in



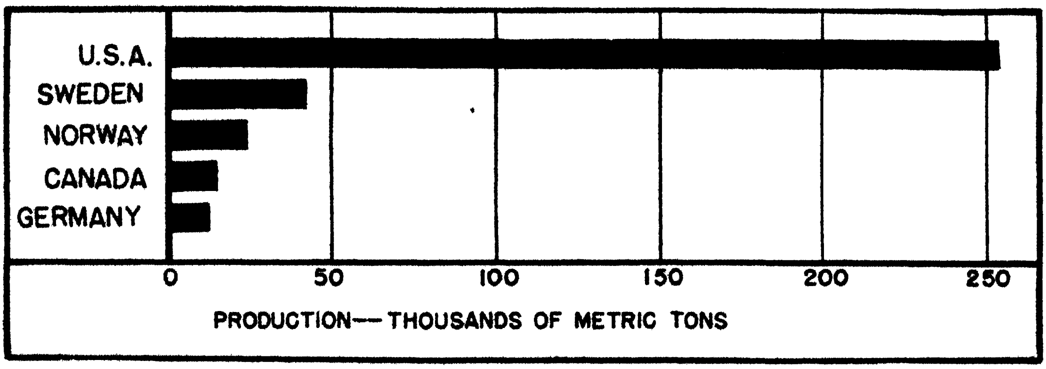
(A.) Production of feldspar, principal producing states. Average annual total for United States during the same period was 362,000 long tons.

from twelve to sixteen states, but the states named provide the major part of the output. The feldspar from the mines is for the most part sold to merchant mills for sorting and grinding, and by them is sold to the factories that make use of feldspar in the manufacture of various products. Ordinarily the ceramic industries use more than 90 per cent of the total output, with glass accounting for 60 to 65 per cent of the total, followed by pottery with about 30 per cent, enamel with 2 to 5 per cent, and soap and other chemical outputs with 1 to 2 per cent. The finest and most carefully selected and prepared ground feldspar is used in the manufacture of artificial teeth.

The feldspars, not so resistant to weathering as is quartz, break down by decomposition and disintegration. The principal products of decomposition are clay, sand, and soluble salts; therefore, feldspar is of great importance in the formation of soils because it is one of the principal sources of mineral salts essential in the soil as plant foods.

The United States produces by far the major portion of the world's reported output of feldspar. However, sizable quantities are produced also in Canada, Sweden, Norway, Germany, and France, with smaller production locally important in numerous other countries. Like quartz, the feldspars owe their importance to their significance as constituents of common rocks and as materials for industry, particularly the ceramic and chemical industries (see Illus. below).

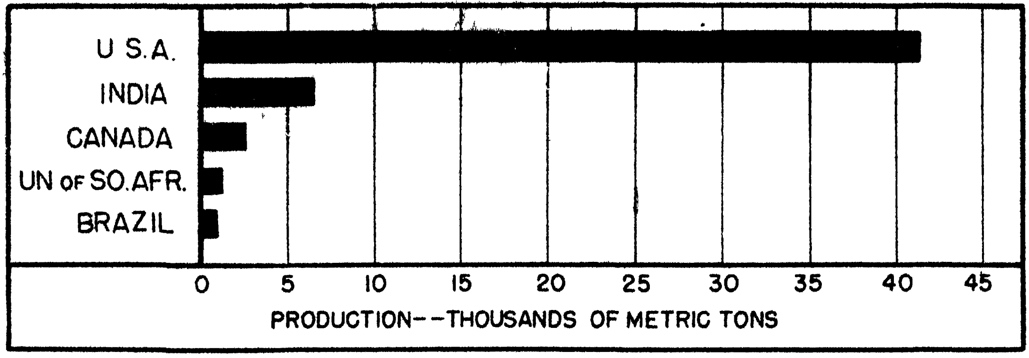
MICA. The term *mica*, also, is used for a group of rock minerals rather than for a



(B.) Production of feldspar, five leading producing countries, annual average 1936-1940. How does one account for the undisputed leadership of the United States?

single kind. The micas are characterized by almost perfect cleavage in one direction and by the thinness and the flexibility of the sheets into which their cleavage permits them to be split. They vary in color from transparent to black.

Where exposed to weathering, the micas break down into small, flaky particles, but as such they withstand decomposition remarkably well. Small mica flakes are common in many of the rocks which have resulted from the deposition of sands and muds, and they can often be recognized in the soil by their lustrous, shining, and flaky properties. The great expansion of the electrical industries during the past two decades has been the principal cause of the increased production and utilization of the variety of mica known as *muscovite*. The unusual combination of physical properties which characterizes it, namely its transparency, elasticity, high dielectric strength, and perfect cleavage, make this mineral indispensable in the manufacture of many types of electrical equipment. Another of the common varieties of mica is known as *biotite*. The high iron content which gives this variety its dark, almost black color impairs the dielectric quality, and the mineral is therefore not suitable for electrical insulation purposes. However, it is used where insulation against heat transfer is desired and, because of its resistance to decomposition and rapid disintegration, it is also used in connection with artificial roofing.



Mica production of the five leading producing countries, 1941-1946 annual average. The mica output of the United States is of the scrap mica type and therefore sheet mica is imported chiefly from Canada and India.

In this country, New Hampshire long held the lead as a producer of sheet mica, but North Carolina has forged ahead in recent years. The bulk of the American mica production consists of scrap mica used in ground form for roofing material and in the paint industry. The roofing and the paint industries together use from 65 to 75 per cent of the total output. Ground mica is sprinkled on roofing material before rolling to prevent sticking of the layers in the rolls, and for the same purpose it is extensively used as a tire powder. It is used also as decorative material on wallpaper, as "snow" for Christmas trees, and for decorative purposes in shop windows, as well as in the movie industry. During the past two decades the amount of scrap and ground mica sold in the United States has more than quadrupled.

Although the United States is the world's foremost producer of mica, domestic production is insufficient to satisfy the industrial needs, chiefly because this country does not produce sheet mica of sufficiently high quality. Imports have generally come from India, Canada, and Brazil. At present, mica mining is assuming importance in the Soviet Union and the Union of South Africa, and it seems probable that additional sources will be added and will remain active in world markets in the near future (see Illus. above).

Hornblende. Hornblende is the most common of the hard, black, brittle, rock-forming minerals. Its hardness is slightly less than that of orthoclase feldspar. It may be of various colors, but dark brown and black occur most commonly. Hornblende has no direct economic use, and therefore its geographic significance is based upon its being a constituent of several kinds of rocks which are used in crushed form for making concrete for construction of buildings and pavements.

CALCITE. Calcite is one of the most common and widely diffused minerals. Although generally found as a component in sedimentary rocks, it occurs also in igneous rocks. The principal reason for the importance of calcite is its prominence as the chief constituent of chalks, limestones, and marble. When pure, calcite is white or transparent, but as found in nature it is usually colored with some impurities. It can be scratched readily with a knife. The common test for calcite is its effervescence in cold, dilute hydrochloric acid.

The direct economic importance of calcite is based on the optical properties of the crystals and on their value as museum specimens; for these purposes there is a moderate market. More important than the demand for calcite in its crystal form is the demand for the products of the rocks—chalk, limestone, and marble—of which calcite is the principal component.

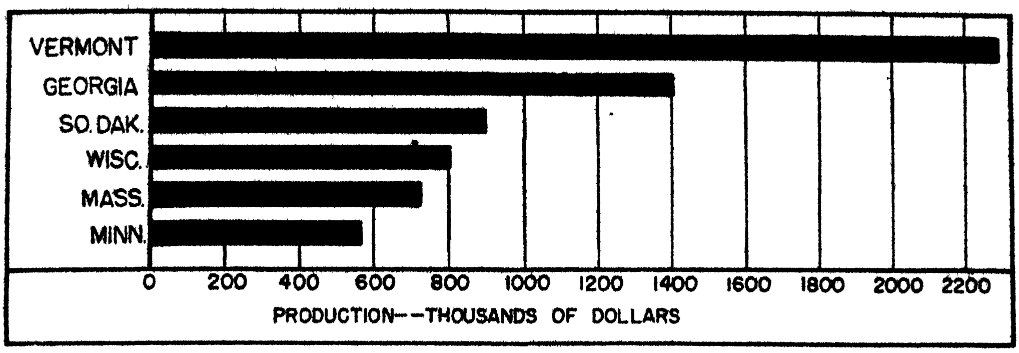
The Most Significant Common Rocks

Recognition of the importance of rocks and minerals in human living is indicated by the terminology applied to the major periods of man's cultural history: the Stone Age, Bronze Age, and Iron Age. Now the term Power Age may be applied to the present recognition of the fact that coal, petroleum, gas, and water are used as sources of energy to do work at man's direction. The latest source of energy to attract world-wide attention, uranium, belongs in the same general category. It is worthy of note that the earliest cultural stage made use of the most widespread of the natural resources, the common minerals and rocks. These, such as flint and quartzite, were most readily obtainable and could be fashioned to simple use.

During these early times, man learned an economic lesson of continuing practical import, namely that with little available power only simple results can be obtained. The mineral or rock to be used had to be easily obtainable and of such structure and texture as to be readily shaped to meet the needs of the times. Thus the lesson of cost was learned, and the conclusion drawn that costs could only be reduced by improved methods of quarrying for the materials needed. This need was met long, long ago by the invention of simple levers and the use of the wheel. Mining and quarrying, from the earliest times to the present, have been confronted by problems of finding and using natural stores where most favorably located for winning the products needed, and of devising efficient means of applying power obtainable from energy sources other than man himself.

The mineral aggregates referred to as the *common rocks* are usually classified, on the basis of origin, into three main divisions: *igneous*, *sedimentary*, and *metamorphic*. The igneous rocks presumably have hardened from a molten stage. The sedimentary rocks consist of small rock particles which have been deposited in more or less regular beds by wind or water action. The term *metamorphic* refers to rocks that have been altered substantially by physical or chemical processes since their original formation. Metamorphic rocks are "changed form" rocks which may previously have been either igneous or sedimentary.

The igneous rocks: THE GRANITES. The mineral components of granites are essentially quartz and feldspar, and most granites also contain mica and hornblende. These mineral constituents occur in various proportions and with differences in size and arrangement, and as a result there are many kinds of granite. They occur in various colors, some light gray, some reddish or brownish, and some quite dark. The structure is wholly crystalline, but the crystals vary from large to small. On the whole,

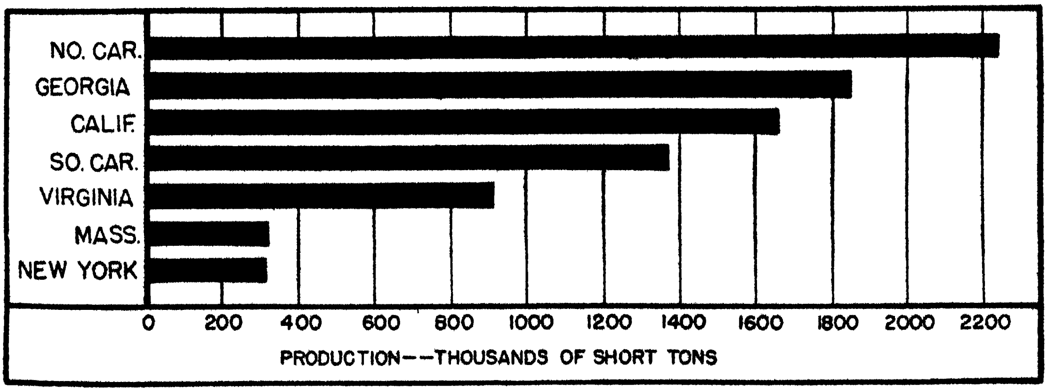


(A.) Production of granite dimension stone by principal states, annual average, 1940-1945. Vermont's leadership is due to the output of monumental stone, a product of high value per ton.

granites are relatively durable, this being especially true of the finer textured varieties. Most of the varieties of granite are capable of taking a high polish and hence are in great demand for ornamental and monumental purposes. Although all granites are compact and hard, most of them are not too hard to be worked readily; it is therefore possible to fashion them into desirable shapes without undue expense for labor or equipment.

Granites are common in nearly all mountain areas. They are widely distributed in the crystalline Appalachian highlands of eastern United States and in the western mountainous areas; they are also found in large quantities in northern Michigan and Minnesota (see Illus. p. 297). In Europe, the mountainous areas of Scotland, Norway, and western and northern Sweden produce granites that are widely known for their beauty and value for monumental and structural purposes. Granite is conspicuous also in the cores of the lofty mountains of southern Europe, especially in the Pyrenees, Alps, and the Caucasus.

Because of its massiveness and durability, granite is a favorite stone for use in masonry construction. It remains attractive even after long exposure to the devastating influences of severe weather changes. These properties of beauty and durability have, to a large extent, caused granite to displace marble for monumental purposes in areas where the climate is such as will break down weaker materials. Granite should therefore be thought of as serving two great and important uses: (1) for monuments of beauty and durability and (2) in crushed form or in roughly shaped blocks for con-



(B.) Quantity production of crushed and broken granite by principal producing states, annual average 1940-1945. Used mostly in construction work and roadbuilding. Note absence of Vermont from this list.

struction purposes either as a matrix in cement construction or as dimensional stone for buildings where durability is of paramount importance. The tonnage of the crushed or roughly hewn granite far exceeds that of the tonnage used for monumental purposes, but the value of the latter is the greater (see Illus. A and B, p. 293).

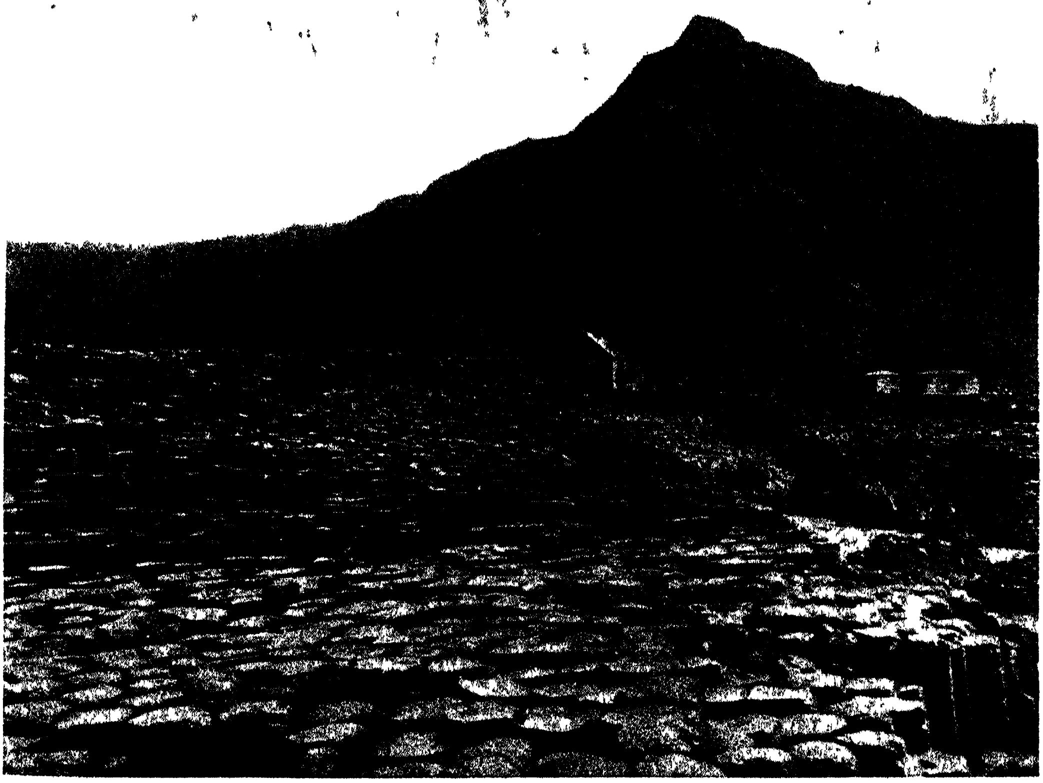
In the United States the leading granite-producing centers are in the East, from New England to North Carolina. See Map, page 297. In value of production Vermont is the leading state, although several other states produce greater tonnage. Barre in central Vermont furnishes the most widely used monumental stone in the United States. The popularity of the Barre granite may be attributed to its pleasing gray color, uniformity of texture and structure, massiveness, and durability (see Illus. below).

Massachusetts has a number of quarries and plants for the preparation of granite

Courtesy Rock of Ages Corporation

View in one of the prominent granite quarries in the Barre district of Vermont Note large blocks of even color and texture The fluted parallel marks are made by the pneumatic drills for the trade, but those near Quincy, a suburb of Boston, are the most famous. This quarry center has been in operation since early colonial days. The Quincy granite, of attractive color and capable of taking a beautiful finish whether rough or polished, is used for construction, and to a lesser extent, for monuments. Maine's prominence as a granite producer is due largely to the seaside location of her quarries, which have proved to be a valuable source of supplies for construction materials needed by the eastern seaboard cities.

Other important granite-producing areas are at Mount Airy, North Carolina, and near Richmond, Virginia, the former famous for its white granite and the latter for its pink. Stone Mountain, Georgia, is a great mass of fine-textured, light-gray granite, suitable for the work of carving attractive monumental forms. The Wisconsin-Minnesota area is likewise an important producer of granite with Montello and Wausaw, Wisconsin, and Ortonville, Minnesota, well known to the monumental stone trade. There seem to be continuing tendencies in the granite-quarrying industry for larger scale operations and fewer production plants. From 1909 to 1946 the number of enterprises quarrying granite in the United States dropped from 707 to 132, with relatively little change in the value of the total output. Indications are that this number is still dwindling and may continue to do so because of the increasing efficiency of machine methods of quarrying and of stone



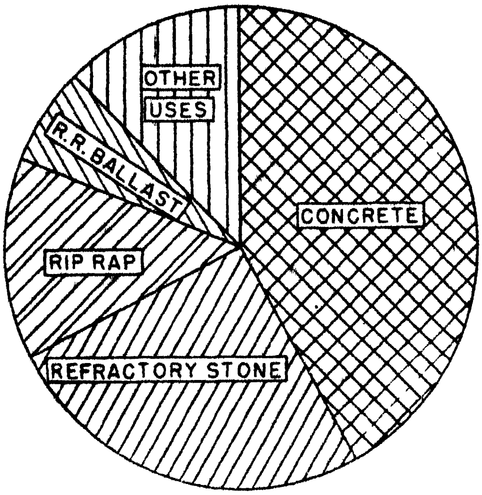
Courtesy of Associated British and Irish Trailways, Inc

The Giants' Causeway near Portrush, Ireland, is one of the best known exposures of columnar basalt in the world. Because of the uniformity of shape and structures these columns were believed to have been the work of giants and thus gave rise to many interesting myths which are still believed true by some people dressing. Machinery for this purpose is costly, and adaptable only to large-scale operation. The economies made possible by modern machinery and power outweigh the handicap of distance to markets, and this leads to the closing down of small quarries where the stone is less desirable or where mechanical equipment is not modern.

THE BASICS. The igneous rocks included under the general term of *basics* are characterized by their dark color and the presence of only a small percentage of quartz. The most common examples of this class are diabase, basalt, and various lavas. Basic rocks occur as prominent ridges in the Connecticut Valley, where they are commonly referred to as *trap*. They also make up the well-known Palisades of the Hudson and the trap ridges of northern New Jersey and eastern Pennsylvania. The most extensive area of basics in the United States is the Columbia Plateau of Washington, Oregon, and Idaho.

Because of the unattractive color, the demand for rock of this group is limited almost entirely to road-making purposes, riprap work along streams, and railroad ballast. The tonnage of annual output is greater than that of granites. While the direct industrial uses of trap and basics in general are not greatly varied, the basic rocks are of importance because they are the source of much of the clay of the land; and their iron content, through oxidation, has caused widespread brown colorings in soils and subsoils as well as in the sedimentary rocks.

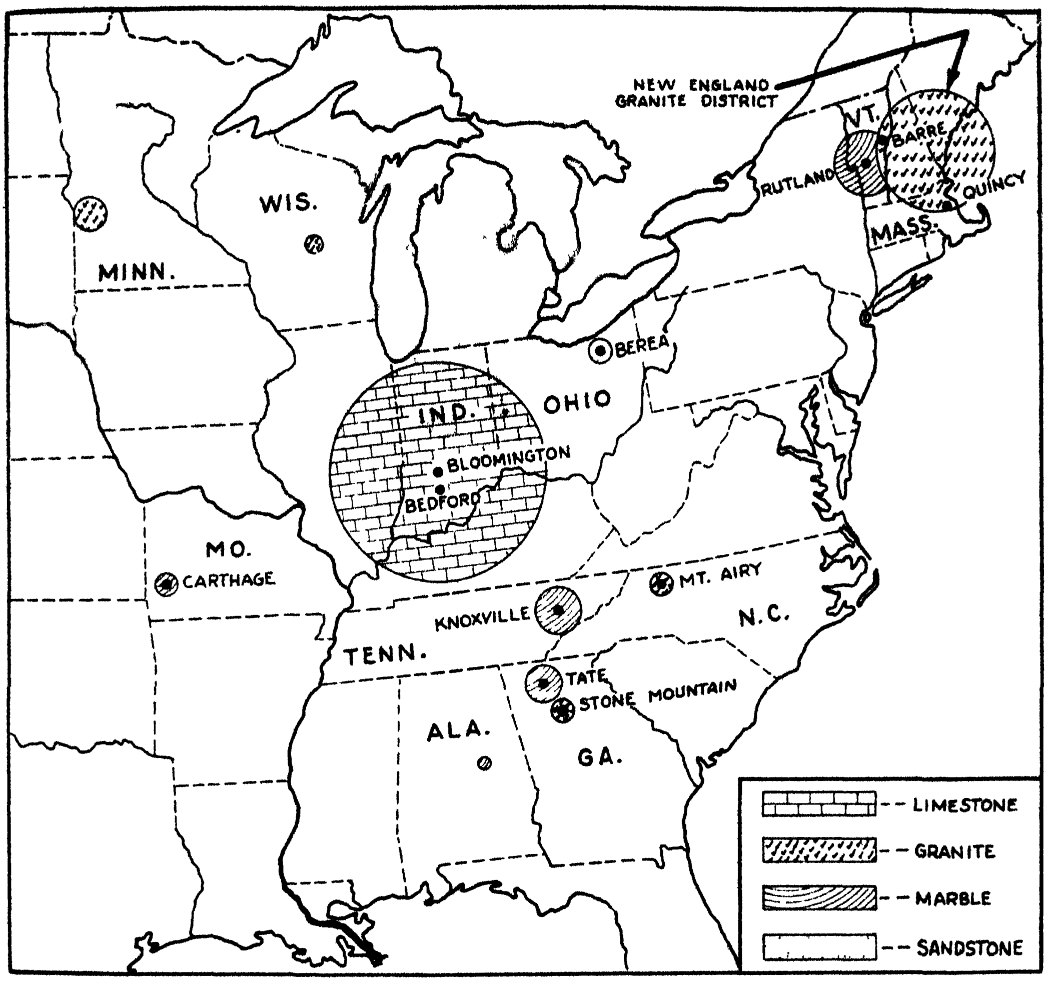
The most common secondary rocks: 1. SANDSTONE AND CONGLOMERATE. The terms *sandstone* and *conglomerate* refer to rocks made up of small rock fragments varying in size from very fine sand to pebblelike bodies. If the grains are quite small, the more or less indurated rock to which they give rise is termed *sandstone*, whereas if the particles are pebblelike, although intermixed with some finer grains, the resulting rock is known as *conglomerate*. The hardness refers to the degree of cementation which exists. Some sandstones are so compact and firmly cemented that they make durable building material. However, in many cases such durable sandstones are difficult to prepare in the desired sizes, or they may be of colors not prevalently desired in the building industry. As a result, sandstones do not meet with great favor for dimension purposes but are in considerable demand as crushed rock for use in concrete work. The use of sandstone for abrasives such as grindstones was formerly important, but in later years this demand has been met to a large extent by artificial abrasives.



Graphic illustration of the principal uses of crushed and broken sandstone in the United States in 1946. Students should measure the angles of the several sectors to determine the percentages shown. Total output was 4,093,000 tons.

At present the four outstanding uses for sandstone are: (1) as dimension stone for construction of buildings and to a lesser extent as flagstone for pavements and sidewalks; (2) for glassmaking, but for this purpose only comparatively pure sandstone can be used; (3) as crushed or broken stone for matrix in concrete work; and (4) for refractory tile and brick. The latter, known in the trade as *silica brick*, is used where the material must be subjected to high temperatures without fusing (see Illus. above).

Ohio, with Berea as the producing center, has undisputed leadership in the output of dimension sandstone. The state ordinarily produces from 40 to 50 per cent of all the commercial dimension sandstone quarried in the United States. In the realm of crushed and broken stone, leadership has long been held by Pennsylvania, but recently California has been increasing its output to the point where it is a strong competitor in tonnage with Pennsylvania. However, Pennsylvania's output is used largely for glassmaking and for refractory tiling and brick, whereas the output in California is used almost exclusively for concrete work. Pennsylvania therefore leads substantially in value although its tonnage is but slightly greater than that of California. Wisconsin competes with Pennsylvania in value because there also the output is used for the manufacture of refractory brick and tile, as is likewise true of Ohio. Thus, in total tonnage Pennsylvania and California may be considered to be the leading states, whereas in value the three leading states, closely competitive, have recently been Pennsylvania, Wisconsin, and Ohio (see Map, Illus. above).



Principal quarry districts of eastern United States, based on relative values and prominence of the centers of the different kinds of rock produced.

The number of commercial sandstone

quarries in the United States has been declining steadily during the past decades, dropping from 1,158 in 1909 to 52 in 1945. The quarries that are being successfully operated at present are those located in areas of great demand for matrix to be used in concrete work. The crushed sandstone used for this purpose is a commodity of low value per unit of weight, and transportation charges therefore become a barrier to long shipments. On the other hand, for dimension purposes the quarries that can furnish the kind and color of stone demanded by the trade remain in successful operation because this type of output has a higher value per unit of weight than is true of the crushed rock for concrete work. In all these cases, however, machinery equipment which makes low-cost ouput possible is an essential.

2. CLAYS AND SHALES. The term *clay* applies to earthy substances of fine texture, consisting of mixtures of aluminum silicates with fragments of other materials of either mineral or organic nature. Consolidated clay is termed *shale*, and the chief distinction between shale and clay is that shale ordinarily manifests a definite tendency to split apart along the planes of deposition. If ground fine and mixed with water, shale very often becomes as plastic as clay.

As to origin, there are two main classes of clay, *residual* and *transported*. Many clays result from the chemical weathering of feldspars, hornblendes, and similar minerals. It will be recalled from previous discussion that the principal products of this type of weathering are clay and soluble salts. When weathering causes the decomposition of feldspars, the salts are carried away in solution, while the clay remains in place, usually with some impurities, such as grains of sand or mica flakes, as a mantle covering the underlying bedrock. Clays thus originating in place through decomposition of the bedrock are classified as *residual;* in some cases the resulting clays are nearly pure and are known as *kaolin* or *china clay*.

Transported clays result primarily from the erosive activities of streams and the subsequent deposition of the debris in water bodies. The coarse detritus, such as gravel and sand, is deposited mostly along the stream courses or near shorelines, whereas the finest particles are swept farther out where they settle in stagnant waters or offshore in the sea. There they form layers or beds and thus give rise to *sedimentary* clays. Beds so formed are often many feet thick and of vast extent but usually do not have as high percentage of kaolin and low percentage of impurities as do clays derived directly through the weathering of rocks rich in feldspars.

Clay in some form enters extensively into construction work and in a large variety of manufactures, and it is indispensable in the arts. The total annual production of raw clay in the United States varies from 18 to 35 million tons, reaching values from 40 to 60 million dollars.

The importance of clay as raw material in manufactures is clearly shown in the value of the products, which is ordinarily more than 250 million dollars per year. In the category of clay products, brick and tile take the lead over all others by a large margin. Of brick alone, the annual output was almost 8 billion in 1925, but since then the general trend has been that of irregular decline because of the increasing use of cement. In the manufacture of brick and tile the heating agent is of great importance, and therefore, near some of the coal-mining centers, brick pavements rather than concrete pavements are common. The future of the brick and tile industries will probably be one of increasing economic importance as wood for building purposes becomes scarcer and more expensive.

Pottery ranks second among the clay-products industries of the United States. *Pottery* is a term rather loosely used to cover the manufacture of earthenware varying from ordinary inexpensive flower pots to the high-grade chinaware that graces the tables of the wealthy. In the United States, clays for the coarser types of pottery are plentiful, but the domestic production of high-grade clay for use in porcelain or chinaware has not been found large enough to meet the demand, and consequently this country imports large quantities, sometimes in excess of 200,000 tons annually, from England and northwestern Europe. The imports go largely to Trenton, New Jersey, and East Liverpool, Ohio, the two best-known centers for the manufacture of high-grade pottery in this country. Other important centers of manufacture are Youngstown, Akron, Zanesville, and Cincinnati. The last-named center is noted for its manufacture of distinctive American art pottery. Ohio has a variety of clays, cheap fuel, excellent transportation facilities, and large markets easily available, factors that favor pottery making. On the other hand, high-grade foreign clays available at minimum cost because of location at tidewater, large local supplies of coarse clays, extensive markets, and a dependable labor supply give New Jersey the basis for a great pottery industry, notwithstanding higher costs for fuel. On the west coast, California has won high rank in production of artistic tableware of high quality and the trend appears to favor further increase in the future.

Courtesy Josiah Wedgwood and Sons, Ltd., Stoke-on-Trent, England

The Thrower "Throwing" is the most ancient method of making pottery. The thrower's attendant prepares a ball of clay, having first weighed the exact amount required for the piece to be thrown. This ball of soft clay is thrown on the wheel and the thrower works the rotating mass into a cone He then opens it by pressing his thumb into the middle and pulling the clay up into a cylindrical shape. Finally, with one hand inside and the other outside, he forms the piece

CLAY MANUFACTURES IN FOREIGN COUNTRIES. The term *chinaware* reveals a recognition of the fact that manufactures of high-class goods of this type originated in China. Europeans, however, by revival of Chinese skill and processes and the added impetus of European art, have put the industry on a commercial basis (see Illus. p. 299 and below).

The modern phase of the chinaware industries was initiated by the Germans in the eighteenth century; since then, world-famous porcelain and pottery centers have developed in various European countries. Numerous factories in Germany manufacture fine porcelain for export, the best-known factories being the centers at Dresden, Meissen, and Berlin. While the German exports of chinaware have usually exceeded those of any other country, Austria, Czechoslovakia, and Denmark all have important porcelain and pottery industries and each has its large following of devoted admirers. During the past two centuries or more France has been Germany's principal competitor in the manufacture and sale of fine chinaware prepared from the high quality of kaolin found on the flanks of the Central Plateau. Limoges has won wide recognition for its output of Haviland china, which is in high favor in European countries as well as in the United States.

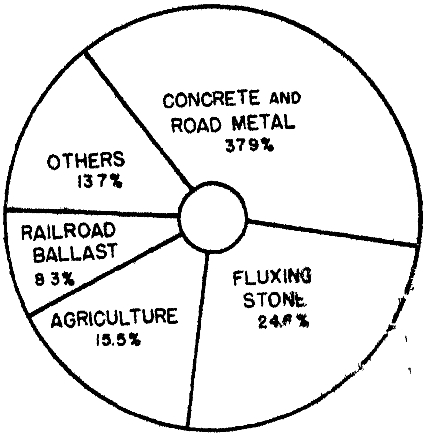
Courtesy Josiah Wedgwood and Sons, Ltd., Stoke-on-Trent, England

"The Modeler" who designs and forms the final decorations on the pieces of fine pottery. Since shrinkage of the ware occurs through drying and firing, the modeler must be able to allow for changes involved if final results are to be highly artistic.

The seat of the British chinaware industry is in west central England about midway between Birmingham and Manchester. There cheap coal, an abundance of coarse clays, skilled labor, and excellent transportation facilities offset the disadvantage of shipping in the fine clays a distance of two hundred miles from Cornwall and Devon in southwest England. The greatest overseas markets for English chinaware are in Canada and Australia, but large quantities are exported also to the United States and to the South American countries.

In the manufacture of coarser clay products such as brick and tile the old countries of north and northwestern Europe are important, because the lowlands are densely populated and neither stone nor lumber is locally available in adequate quantities for building purposes. Clays are plentiful, coal is relatively low-priced, labor is available, and construction materials are in demand; therefore, the manufacture of brick is a logical development. Brick-walled houses with tiled roofs are inseparable features of the landscape in England and in the lowlands of northwestern continental Europe. The Dutch use tile for interior as well as for exterior decoration, the Delft ware being particularly famous for such purposes.

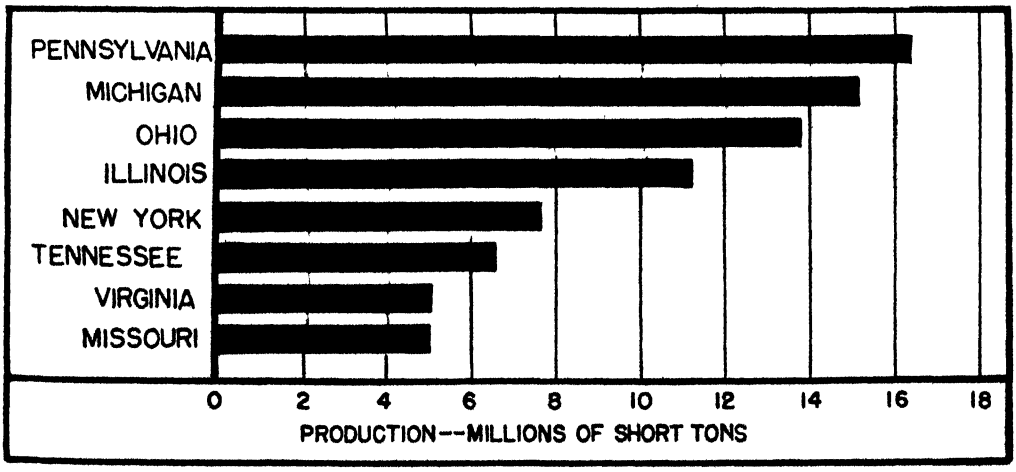
FUTURE OF THE CLAY-WORKING INDUSTRIES. The growing use of brick for building purposes—walls, tile shingles or roofs, tile for water mains, sewer pipes, and drainage tubes—together with a widespread abundance of raw materials, will probably result in further expansion of the coarser clay manufactures. In the United States the depletion of the forest resources and the gradually increasing density of population will direct attention more and more toward clay products for building purposes. The growing population and the increasing standards of living offer continually expanding demands for utensils, chinaware, and bathroom porcelains. As the general prosperity of the country increases, the demand for the finer qualities of manufactures will grow apace. Under these circumstances it seems inevitable that all phases of the clay-working industries, the brick and tile on the one hand and the finer porcelains on the other, face gradually expanding markets and a hopeful future.



Graphic illustration of principal uses of crushed limestone. How is limestone used for agricultural purposes? What is meant by "fluxing stone"?

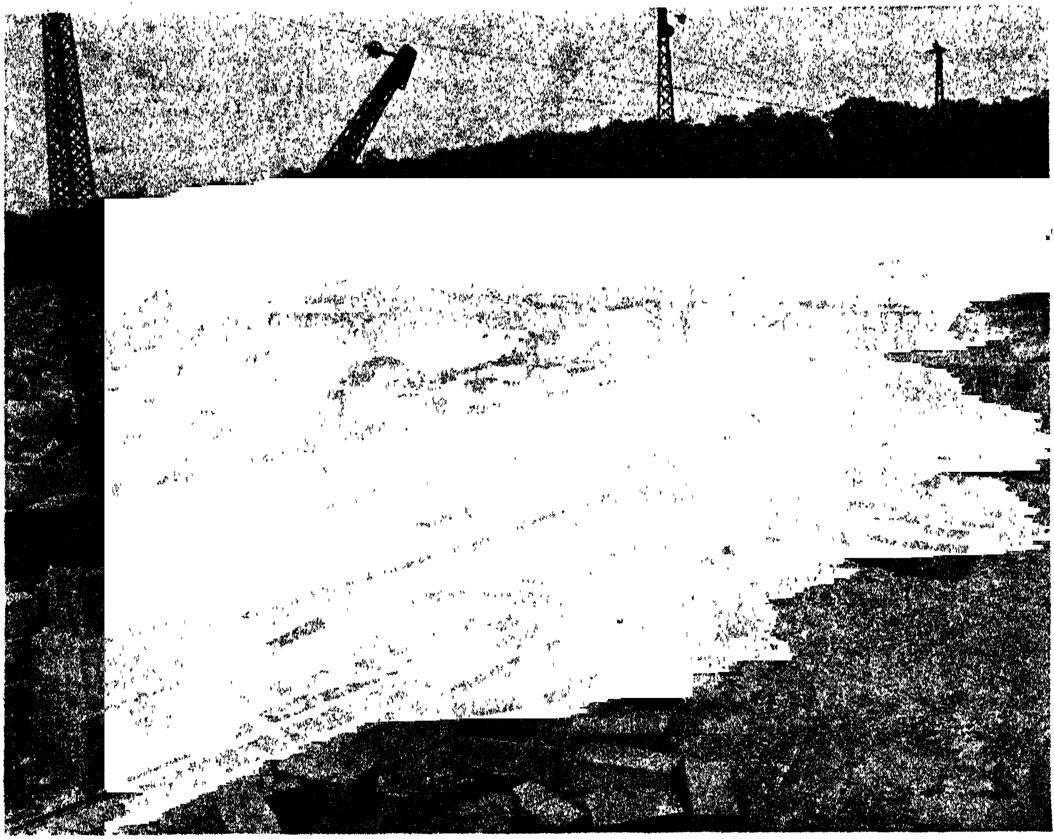
3. LIMESTONE. Limestone is essentially lime carbonate ($CaCO_3$), but ordinarily it contains impurities, such as clay, silt, sand, and various minerals, in varying proportions. In some cases the impurities constitute less than 1 per cent, while in others they may make up nearly 50 per cent of the whole. Limestones vary in color, the grays and light tans being the most common, but various other colors, such as brown, black, red, or blue, are not rare. Hardness varies with density and structure; some limestones are soft and porous, others, hard and dense.

PRINCIPAL USES OF LIMESTONE. Limestone is used most extensively as crushed rock in concrete work, particularly in pavements, foundations, and in building construction. It is the principal raw material in the manufacture of cement, and it is the bulky ingredient of many commercial fertilizers. Limestone is well known for its extensive use as dimension material for the walls of buildings, but it has other important uses as well. One of its most important markets is in connection with smelting industries for use as fluxing material, especially in the reduction of iron ore. It is used in connection with sugar refining and in the manufacture of quick lime, for which purposes a relatively pure limestone is necessary. Because of the variety of its uses, limestone may rightly be classified as one of our most important mineral resources (see Illus. above).



Average annual production of crushed and broken limestone by leading states, 1940-1945. The average annual total for the United States was 13,273,000 tons. The crushed limestone did not suffer as serious a decline as did the dimensional limestone.

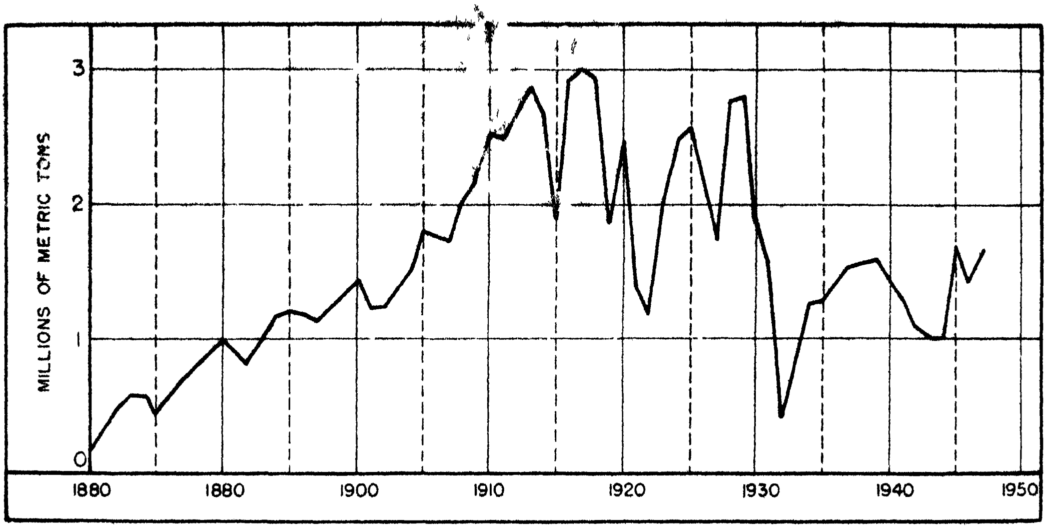
Production of Limestone in the United States. The output of limestone in the United States has shown rather steady increase for a number of years. Of late it has accounted for approximately 60 to 75 per cent of the entire commercial stone production of this country. That limestone quarries are widely distributed is shown by the fact that forty-four states reported commercial production in 1946, the only ones not included in the list being New Hampshire, Delaware, Rhode Island and North Dakota. The states which ordinarily lead in value of output are Pennsylvania, New York, Ohio, Indiana, Illinois, and Michigan, although the order varies. Of the total tonnage produced, 65 to 75 per cent is in the form of crushed stone, used mostly in concrete, with fluxing and agricultural purposes ranking second and third. The dimension stone produced is used almost entirely for construction purposes. The amount used in agriculture either by direct application to overcome acid soils or as an ingredient in commercial fertilizer is increasing rapidly.



Courtesy Indiana Limestone Company, Bedford, Indiana

View in one of the quarries near Bloomington, Indiana. Note the extensiveness of the operations, the huge derricks and other equipment, and the large blocks obtainable.

The most famous quarries of building limestones are located in southern Indiana, with Bloomington and Bedford as the principal centers (see Illus. p. 297). The Indiana limestone is the most widely used natural stone for dimension purposes in this country. Its markets extend from the Atlantic seaboard to the vicinity of the Rocky Mountains. Among the reasons for its popularity are its pleasing color, its uniform structure, the thick beds from which it may be quarried, the low cost of quarrying and milling into desired forms, and the uniform and attractive appearance. The color is an attractive gray when the stone is weathered as well as when it is freshly quarried. The limestone produced in most of the states outside of Indiana is used chiefly in concrete work for building foundations and street pavements, as fluxing material, and for agricultural purposes. The high development of construction industries and the extensive road-building programs in progress throughout the country provide large and expanded markets for limestone in nearly all the states.



Annual production of dimensional limestone since 1925. Note the effects of the depression period of the 1930's and the war period of the 1940's upon this industry.

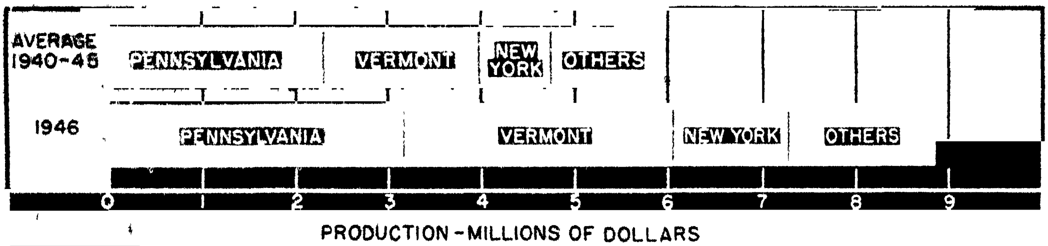
Trends in quarrying and utilization of limestone. The ease with which concrete can be poured into any desired form and the durability of foundations, walls, and pavements thus made combine to reduce the demand for limestone for dimension purposes. The Indiana limestone has, and will probably continue to have, substantial and widespread markets, but dimension stone from other sections finds competition with the various forms of cement rock difficult to meet. However, the tendencies are definitely toward larger quarries, complete mechanization, and economy of operation. It is probable that the economy of operation made possible by large-scale production in favored localities will largely offset the increased costs of transportation for longer distances and thus permanently keep the total number of quarries in operation at a lower figure than was true in the earlier stages of the industry. (Illus. p. 302.)

The most common metamorphic rocks. As already stated, the metamorphic rocks are those that have been changed by pressure or chemical cementation from an earlier primary or secondary form. The most common are known as gneiss, schist, quartzite, slate, and marble. Of this group, the first three named, while they occur rather widely and are used to a minor extent for roadbuilding and for construction, can hardly be ranked as rocks of high industrial significance. Although locally important in a few places, including such prominent centers as New York City and some of the west coast cities of the United States, their total output is small and does not justify extensive treatment. The two last named, slate and marble, however, are more important nationally and even internationally, and therefore they warrant brief treatment here.

Slate. Slate was used for roofing material in the British Isles more than three centuries ago. The Penrhyn quarries near Bethesda in North Wales boast that they have been in continuous production since the period of Queen Elizabeth and that as early as 1792 part of their output was marketed in the New World. It is claimed that some of the headstones that mark the graves of the early pioneers in New England towns came from this source and that the carvings upon some are still legible.

Slates are metamorphic rocks derived from clay or shale. The term is applied to fine-grained rock that has almost perfect cleavage, permitting it readily to be split into thick, smooth sheets. It includes materials that differ widely in color and even in composition, but it consists of such weather-resistant natural minerals that it is recognized as one of the most enduring structural materials. The value of slate depends upon its well-defined planes of splitting, which render it serviceable as slabs or thin sheets for various purposes such as roofing, sanitary and chemical ware, and blackboards. In preparing these slabs, however, the percentage of so-called waste is high, sometimes running up to 60 to 75 per cent. But this material is not waste in the ordinary sense. The scrap slate that results from milling into slabs, as well as the scrap derived from quarrying processes, is ground into flour or granules. The total quantity of slate flour and granules provides a tonnage seven to eight times as great as the tonnage marketed in the form of slabs or sheets. The value in proportion to weight of dimension slate is of course much greater than that of the flour or granules, but the total value of the latter ordinarily exceeds that of the former.

The states that lead in slate production in the United States are mostly in the eastern part of the country, with Pennsylvania, Vermont, and New York occupying the foremost positions, while on the west coast, California produces quantities of some magnitude (see Illus. below).



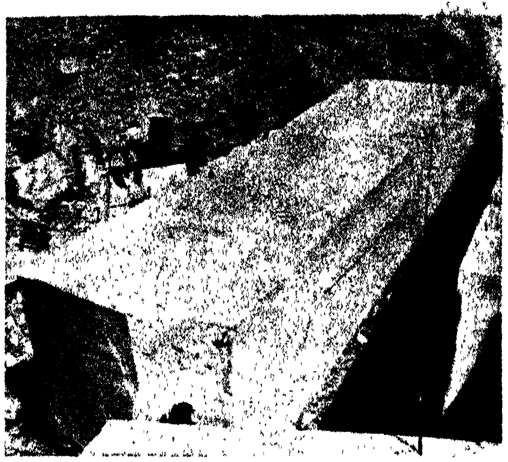
Slate production, principal states, on basis of values of output, annual average 1940-1945, and for 1946. Beginning of post-war recovery shown. This continued through 1948 when total value of output reached $12,881,000 with little change in relative positions of producing states.

The durability of slate and its pleasing appearance account for its continued popularity for roofing purposes. In the present trend of manufactured roofing, many of the kinds prepared make use of some form of slate, particularly the granules, and since this phase of the roofing industry appears to be definitely on the upgrade, the result will be to provide expanding outlets for products of the slate industry that early were considered to be of little economic importance.

Marble. Marble is a metamorphic rock, but the trade applies the term to any calcareous rock capable of taking high polish. Although marble is white when pure, because of impurities and differences in structure it often varies in color from white to dark blue, green, and even black.

In value of output, marble ordinarily exceeds slate in the United States by 25 to 30 per cent. The states leading in production are Vermont, Tennessee, Georgia, and Missouri, their output being about 80 to 85 per cent of the nation's total. Vermont usually leads with its principal quarry centers on the west flank of the Green Mountains. Marble from these localities varies from almost pure white to gray and pink, and some varieties have intricate veins of green or brown.

Knoxville, Tennessee, is in the midst of the marble-producing district of that state. Tennessee marble varies from white to mottled maroon and is widely used for floors and decorative interiors. Georgia marble is used for construction purposes and some years ago won renown because of its use in building the territorial capitol of Puerto Rico at San Juan. The most famous statuary marble in the world is quarried near Carrara, Italy, on the flanks of the Apennines. The quarries have been operated there for centuries and have furnished the raw material for much of the world's classic sculpture. The texture of the marble is uniformly fine-grained, the color of the statuary marble is snow-white, and the structure is such that flawless blocks may be obtained large enough for any desired use. These qualities have given Carrara marble its world-wide fame and markets (see Illustrations below).



Courtesy I. Bessi, Carrara, Italy.

(A.) Carrara Marble Quarries. Monolith dimensions were reported 8 feet wide, 8 feet deep and 8 feet long, and weight 300 tons. Note uniform texture and structure of stone color white. World's most famous statuary marble.

Courtesy I. Bessi, Carrara, Italy.

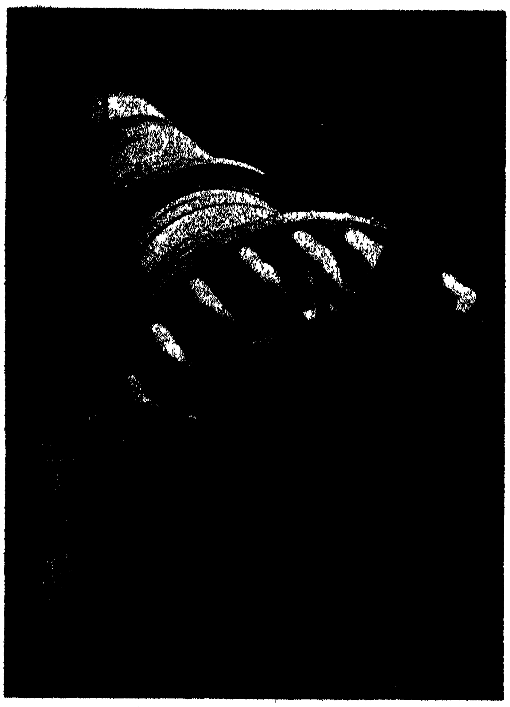
(B.) A statue in the process of being hewn out of a large block of Carrara marble. The reduced scale plaster model in left foreground serves as a guide for sculptor's work. Importance of perfection in original block is apparent.

Although the demand for marble as monumental stone is declining because of its deterioration under the ravages of the weather in the middle latitudes, the demands for marble for interior finish are growing steadily. For general construction purposes, marble seems assured of substantial markets wherever transportation charges are not so high as to limit its use in favor of lower cost competitors. In common with other materials, marble will be affected by the pulsation of style; it will undoubtedly have its periods of high demand and of market recession, but there seems little doubt that it will always remain an important element of the mineral industry of Europe and the United States.

The cement industry. In early days cement was made by mixing slaked lime with volcanic ash, which resulted in hardness and remarkable durability. Such cement was used by the Romans in building bridges, surfacing roads, and constructing aqueducts and is still being made near the volcanoes of Italy. It is known as *Puzzolan cement.* The industry declined and was virtually nonexistent until building of extensive fortifications was undertaken in the latter part of the seventeenth century. Europeans then had learned that a cement similar to Puzzolan could be made by heating some impure limestones to high temperatures, and to this product the term *natural cement* was applied.

Courtesy Portland Cement Association, Chicago, Illinois.

(A.) Limestone crusher in cement plant. The hopper of a gyrator crusher is about 16 feet across and engulfs a whole dump car of rock of assorted sizes within two or three minutes.



Courtesy Portland Cement Association, Chicago, Illinois.

(B.) Rotary kiln in cement plant. The kiln, about 400 feet long, is supported by giant roller bearings, and rotates at an average rate of three-fourths of a turn per minute. The kiln is inclined about three-quarters of an inch for each foot in length to facilitate continuous passage of the mixture.

Natural cement was used in building the Erie Canal in 1820 and continued to be the principal cement for construction in the United States until near the close of the nineteenth century, after which Portland cement took the lead and now dominates the field. Some Puzzolan cement is now made in the United States by grinding blast-furnace slag and mixing it with needed lime, but the total amount, including natural cement now being made, constitutes only 1 to 2 per cent of the total production of the cement industry. The term *cement* as currently used presumes *Portland cement,* unless otherwise specifically stated.

Portland cement is credited as a discovery, in 1824, by Joseph Aspdin of Leeds, England. Aspdin, who made cement by heating powdered limestone and clay, found that a mixture of the product with sand would harden under water, thus giving rise to an artificial stone that resembled a sandstone quarried on Portland Isle, England.

Although Portland cement manufacture developed rather slowly in the New World because other building materials were so plentiful, expansion became rapid after the turn of the century, and it now ranks as one of the great industries of the nation. The total annual output has grown to exceed 200 million barrels (weight 376 pounds), with a value of over 445 million dollars.

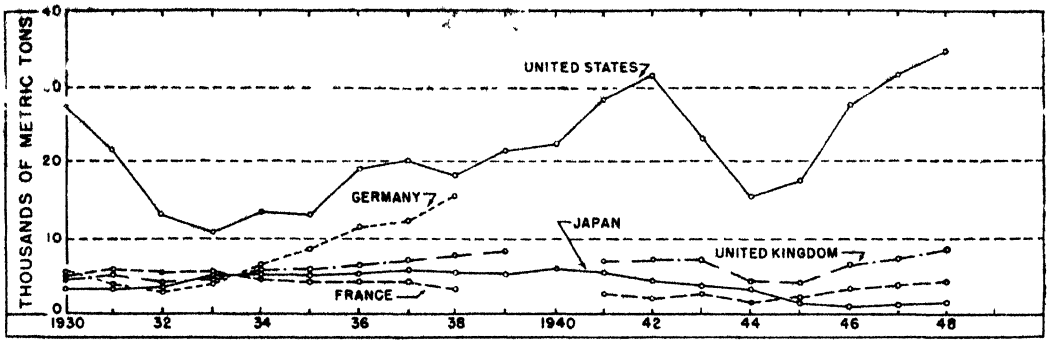
The manufacture of Portland cement involves more than eighty different operations. but the essential features are: (1) selection of raw materials that will provide the essential constituents—lime, silica, and alumina—in proper proportions; (2) grinding of the raw materials, usually limestone and clay or shale, to such fineness that 90 per cent of the resulting powder will pass through a sieve with 40,000 openings per square inch; (3) introduction of the powder in wet or dry form into a rotary kiln 300 feet or more long, where it is subjected to temperatures of 2500° to 3000°F.; and (4) grinding of the fused product of the kiln, which emerges as white hot balls about the size of marbles and is known as clinkers, into a powder finer than flour (see Illus. A and B, p. 306).

During the grinding process small quantities of gypsum are introduced because this mineral serves to retard the rate of setting or hardening of the cement. From this stage of operation, which is known as the finishing mill, the cement is either passed to huge storage buildings called silos or is fed into sacks, each holding 94 pounds, ready for shipment. Statistically, the output is measured as *barrels* of 376 pounds; a *sack* is therefore one-fourth of a barrel.

The raw materials to be used and the products that emerge are subject to continuous physical and chemical tests. The laboratory of a cement plant is a busy place and is as necessary to successful operation as is the kiln or the mill.

The Portland cement industry of the United States is one that in a true sense serves the nation. The number of plants in operation in 1948 was 149, scattered over 35 states. Since the raw materials are of heavy weight in proportion to value, cement factories tend to be localized. Where coal, limestone, clay, and markets are all in close proximity, the cement plants are most numerous. Eastern Pennsylvania meets these conditions and is therefore the foremost center in the United States for cement manufacture. Fortunately, the raw materials are widely and generously distributed over this country, and some kind of heating medium—coal, petroleum, natural gas——is usually available so that all sections can be supplied with Portland cement without unduly long haulage and high expense.

The cement industry, largely an achievement of the present century, has attained the status of a great world-wide industry, the activity of which is viewed as an index of industrial progress. Prior to World War



Cement production in principal producing countries since 1930. Note effects of depression period and of war years upon cement industry of the United States. What is true of the post-war trends?

II the European nations had all achieved varying degrees of prominence in this field, with Germany, England, France, Italy, and Russia in the forefront. Usually Europe and the United States together produce about 80 per cent of the world output, but more than fifty of the other nations and dominions of the world engage to some degree in the manufacture of cement. An even larger number use cement in varying amounts for construction purposes.

Cement deserves high rank as a factor in true conservation. Through it, crushed and broken rock which otherwise would be considered waste now far outranks dimension stone in value of output. This makes possible permanent structures, buildings, bridges, canals, and pavements, with a saving of forest and metallic resources. The use of paved highways makes for efficient use of energy and thus increases output of work at lower expense. The list could be extended almost without end, but we believe that even this brief overview will help the student to gain an insight into the reasons why many industrial leaders look upon the present as the "Cement Age."

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Chapter Nineteen

IMPORTANT MINERALS OF DIRECT ECONOMIC USE

In the previous chapter we considered the minerals which are important chiefly because of their roles as rock constituents, although in most instances some direct uses were found to be important as well. In this chapter, only such minerals are discussed as are important chiefly because of their direct economic value. Their greatest value to man lies in their industrial uses, uses which are possible without conversion into other products through complicated smelting or reducing processes. There are many minerals in this group, but we must limit our study to those which occupy places of high economic importance in the industrial scheme. On that basis, we have chosen to include in this discussion only asbestos, gypsum, salt, sulphur, and the three highly important mineral ingredients of commercial fertilizers—nitrates, phosphates, and potash.

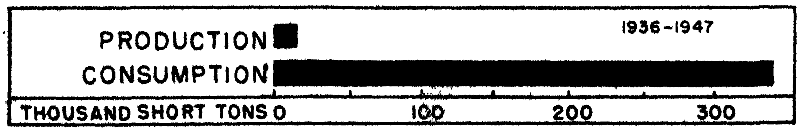
Asbestos

Asbestos is a term applied to certain hornblendes which occur in crystals of fiber form. These are found in veins of varying width and have a structure so nearly perfect that the individual crystals may be used as fibers, pressed into mats, or intertwined into threads of varying sizes and woven into fabrics. The several varieties of asbestos are classified commercially into two groups—the long fibers and the short. The long fibers are in great demand for woven materials to be used in the form of cloth, such as fiber drop curtains in theaters or woven brake linings, and for gaskets and packings in automobile manufacture, as well as for use in power-generating plants. The short-fiber varieties are used for insulating materials to withstand high temperatures and to resist acid action. Its resistance to heat and chemical action and its non-inflammable qualities make this mineral one of the most critical in any economy, whether peacetime or war.

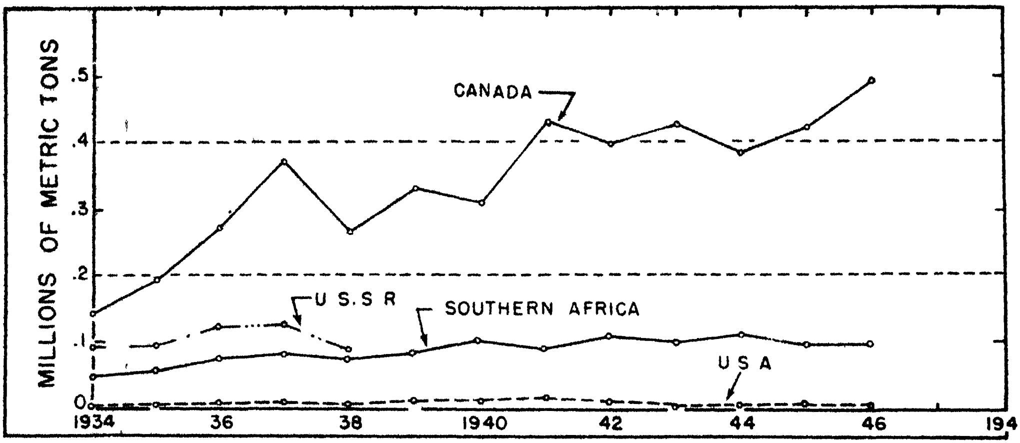
The United States is weak in asbestos. Unless new deposits are discovered, the country must continue to be dependent upon imports for its needed supplies because the present outlook is that not more than 5 or 10 per cent of the demand can be met from domestic sources. Illus. A, p. 310 is a graphic illustration of the relation of the domestic supply to the total annual average consumption during the period 1936-1947. Canada was the source of 91 per cent of the imports.

In addition to its use in the manufacture of automotive essentials, asbestos is used in building construction and for certain types of industrial products; these include wallboard, as well as heat-insulating and fireproofing materials. While small quantities of asbestos have been produced in recent years in nearly a dozen states, Vermont and Arizona seem to have become established as the leaders in the United States.

The principal sources of world supply of asbestos are shown in the accompanying diagram (Illus. below). It will be observed that Canada continues to hold a commanding lead among the nations. That country has long been the chief source of supply to meet the needs of the American construction and machinery industries for this material, which is characterized by little bulk and is of high value. Present indications are that Russia is well provided with this vital mineral, but reliable data are not presently available.



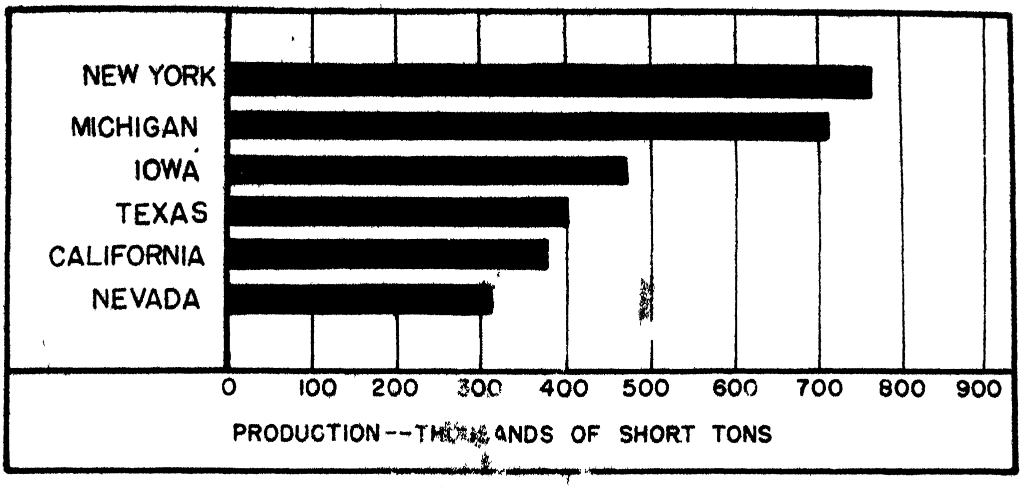
(A.) Average annual production and consumption of asbestos in the United States, 1936-1947. Makes clear the dependence of this country upon foreign sources.



(B.) Asbestos. Principal producing countries, annually since 1934. How does one account for the marked increase of Canadian production?

Gypsum

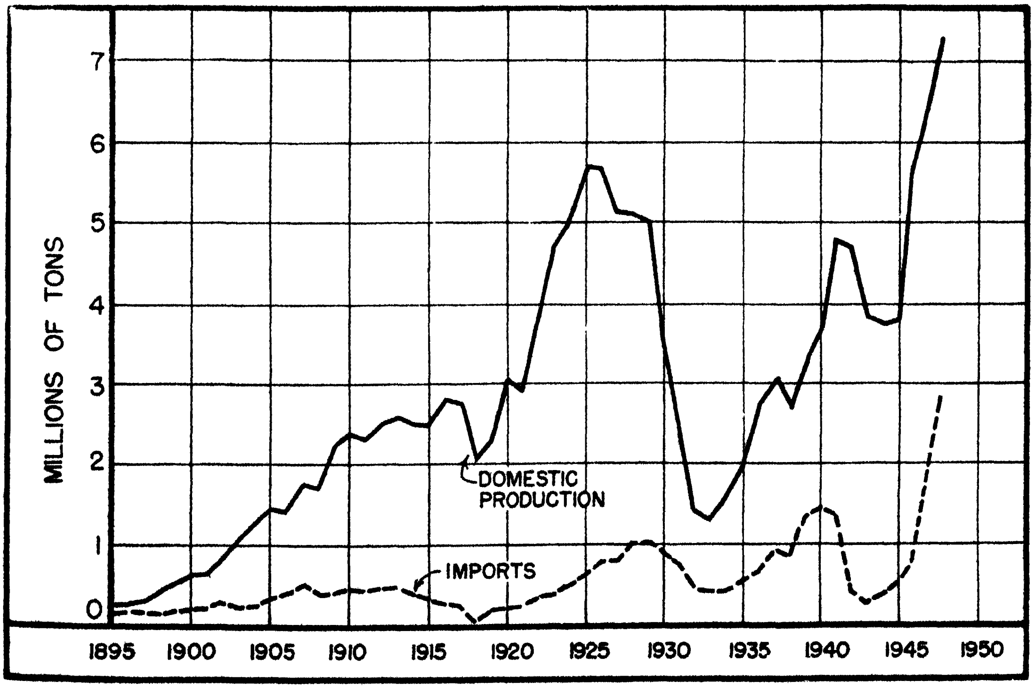
Common gypsum may be used without any processing other than grinding, and considerable quantities are so used. The larger portion of all the gypsum mined, however, is heated to moderately high temperatures, a process called *calcining*, and thus is made into a plaster of wide usage, the purest of which is the well-known Plaster of Paris. The crushed or ground gypsum is used for agricultural purposes because it serves to correct the acidity of some soils; when used in that manner, it is known as *land plaster* but is referred to in the statistics as *agricultural gypsum.* When ground fine, it is used in rather small percentages in the manufacture of Portland cement, in which it serves as a retarder, preventing the cement from setting so rapidly as to be difficult to handle in construction enterprises. These two major uses ordinarily account for 25 to 30 per cent of the total output of gypsum in the United States. The calcined gypsum is used most extensively in the manufacture of building plasters and cements and for prefabricated lathes, wallboard, sheathing board, and tile. These uses far outrank in tonnage and in point of value any of the other uses, although calcined gypsum is also used in the



(A) Gypsum. Principal producing states, annual average 1938-1946. Note the close race for first place by New York and Michigan. How does one account for the prominence of Nevada?

manufacture of plate glass, terracotta, pottery, and orthopedic and dental plasters. High-quality gypsum is almost as important in technical industries as is Portland cement in the building trades.

The annual output of gypsum mined in the United States now varies from about 3½ million to above 6 million short tons per year. Illus. above indicates the average annual output of the leading states during a 9-



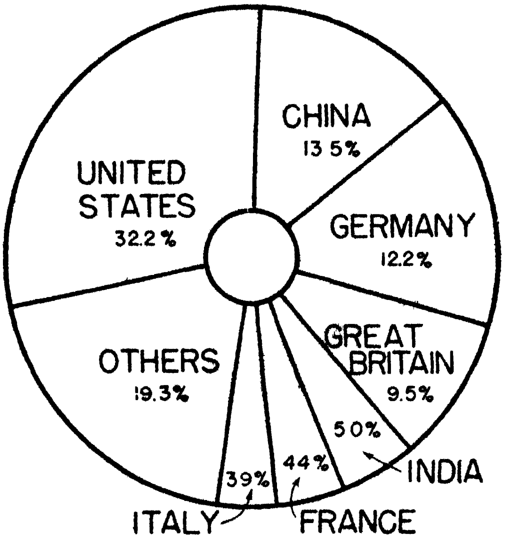
(B.) Gypsum. Domestic production and imports since 1925. Note the dips in curves associated with the war and depression periods.

year period, but it should be added that the more recent trend in Michigan seems to place it definitely in first position, with New York in second place. In any one particular year, however, either of the two states might be in the lead. The same can be said of the close competitive position that has of late been assumed by California, Iowa, and Texas. Although Texas has recently taken the lead, the difference in output among the three states is such that any one of them might outrank the other two in any given year. Some gypsum is imported regularly from New Brunswick and Nova Scotia for use in the northeastern states, where water routes make the Canadian sources readily accessible (Illus. B, p. 311). In world production the United States always has first place by a wide margin, its output in recent years being nearly three times that of the United Kingdom, its nearest rival. Many countries produce varying quantities of gypsum, but in addition to those already named, those which lead in output and in usage are France, Germany, Canada, Spain, and the Soviet Union. During the period immediately preceding World War II, Germany, Russia, and Spain were each credited with an annual output of between 700,000 and 860,000 metric tons.

Salt

In small quantities salt occurs almost universally. It is a minor constituent of many clays, shales, and sands, and it is also present to a slight extent in many soils. It exists in the cavities and pore spaces of some rocks and thus may give rise to salt-water springs and some salt wells. The largest quantities of salt, however, occur in sea water, in salt lakes, and underground in solid beds or masses termed *rock salt.* Rock salt is the source of most of the commercial salt, although there is also important production from the evaporation of waters from the ocean and salt lakes. Rock salt is the basis for extensive mining operations in many countries. Methods of winning the salt vary from underground mining of the solid beds to obtaining it by solution methods, that is, by pumping hot water down to the bed of rock salt, churning it about by specially devised agitating methods, and then pumping up the brine.

Uses of salt. Not so many years ago salt was used chiefly for domestic purposes, and that use still provides the principal demand in most of the nonindustrial countries of the world. However, the recent expansion of the chemical industries in Europe and the United States has led to new and greatly accelerated demands for salt, because this material has been found to be an indispensable raw material for the manufacture of a great number of chemicals. In late years the chemical industries have used from 65 to 70 per cent of all the salt produced in the United States, its major importance being its use in the manufacture of various bleaches, soda ash, dyes, and soaps, as well as numerous other articles.



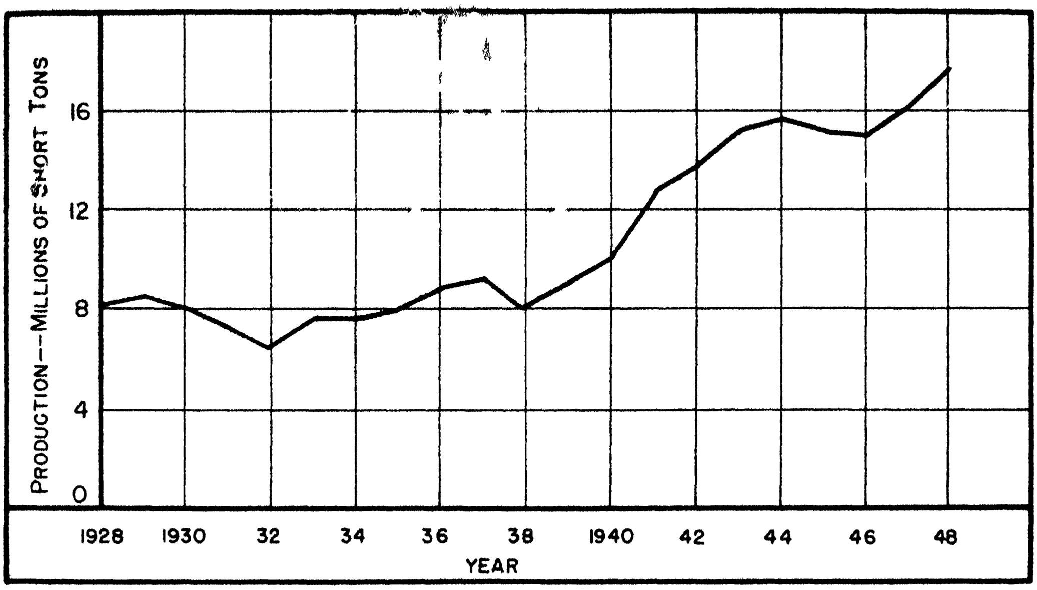
Salt. Percentages of world production by principal countries in 1942.

In the United States in recent years, the use of salt for livestock has ranked second and for table and other household purposes third. Often overlooked is its importance in dust and ice control on highways and railways, a use that in some years requires quantities exceeding the total amount used by the meat-packing and fish-curing industries combined.

Salt is the only mineral which enters directly into the diet of man and beast on a large scale and which is indispensable to their existence. Primitive people showed great ingenuity in their means of securing salt supplies. Among some peoples salt took the place of money. Places where salt could be obtained were declared neutral ground by some of the Indian tribes of the Great Plains. Tribes otherwise hostile would meet at such places and gather their salt in friendly rivalry, whereas meeting elsewhere would at times lead to deadly combat. This practice was a direct tribute to the necessity of salt in man's diet.

Distribution of salt production. Nearly all the countries of the world produce salt in varying amounts, but the United States is far in the lead. Other countries high on the list are Germany, the United Kingdom, China, Italy, France, and India. In the world situation, as in many other aspects of industrial production, statistics dealing with the Soviet Union are conspicuously lacking (see Illus. p. 312).

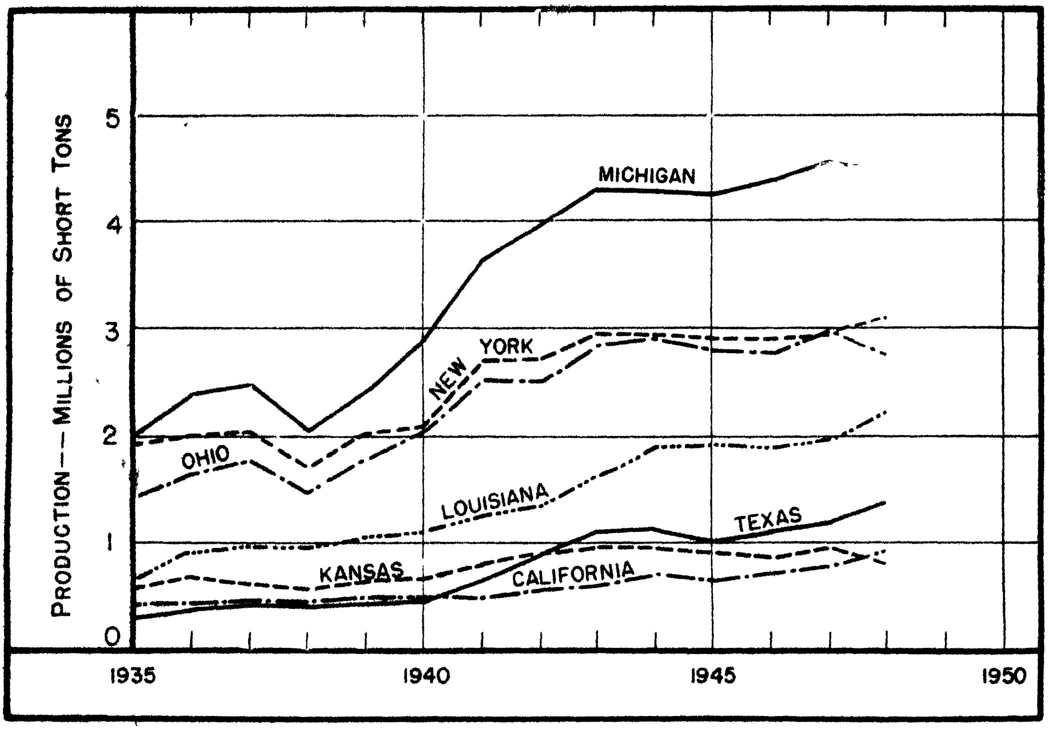
Owing to the great expansion of the chemical manufacturing industries of this country, the production of salt in the United States has practically doubled since the 1920's (see Illus. below). The leading states, as illustrated on page 314, have consistently been Michigan, New York, and Ohio, in the order named. Formerly these were followed by Kansas and Louisiana, in that order, but recent developments have placed Louisiana a strong fourth, Texas fifth, and Kansas sixth. If California continues her trend, she is likely to reach and possibly exceed Kansas. The demands for salt by the increased population along the Pacific Coast and the increased industrialization of the area provide quite an incentive to increased local production. World production has been estimated to range from 30 to 35 million metric tons in recent years, with the United States alone producing nearly 50 per cent of the total. It seems fairly certain that the United States will retain its strong preeminence in salt production through the foreseeable future.



Salt Annual production in the United States since 1928 Why has salt production increased at a more rapid rate than that of population?

Sulphur

Sulphur is widely distributed in igneous rocks, particularly lavas, but it usually occurs in such small quantities and in such association with other minerals that economic extraction is difficult and expensive. The sulphur used in industry is derived from two principal sources: (1) from native sulphur, which is exploited where found in fairly large bodies that are readily accessible, and (2) from sulphides of metals, chiefly iron, commonly referred to as *pyrites.* For many purposes pure sulphur is preferred to the pyrites because it can more readily be converted into desired combinations than can pyrites, and because there is no problem of disposal of waste, since native sulphur is so nearly pure that no waste products result from its utilization. Sulphur from pyrites is derived chiefly from the iron compounds and to a lesser degree from sulphide ores such as those of copper and zinc. Inasmuch as the sulphur content of such ores varies from 25 to 40 per cent, sulphur is a by-product of the smelters that deal with sulphide ores other than iron; whereas, in the case of iron pyrites, sulphur is the valuable element and the remaining part becomes waste because no satisfactory methods of rendering the iron completely free of sulphur have yet been developed.

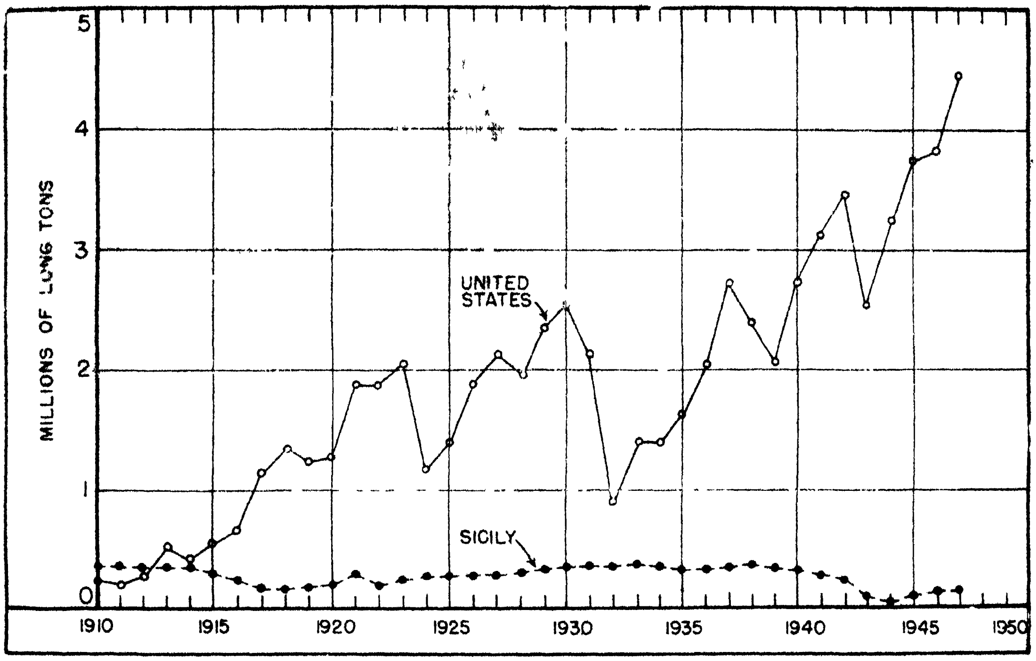


Salt Annual production of leading states since 1935 Which of states shown has had greatest rate of increase since 1935?

Commercial production of native sulphur is restricted to a few areas where large bodies have been discovered under conditions favorable for exploitation. While native sulphur has been produced for a number of years in many countries, particularly in Japan, Spain, and Mexico, most of the world's output is now supplied by the Gulf Coast of Texas and Louisiana and by Italy or the island of Sicily.

Uses of sulphur. The most significant use of sulphur is in the manufacture of sulphuric acid, the most important raw material used by the chemical industries. In addition to this use, sulphur is essential in the manufacture of fertilizers, insecticides, pulp and paper, and explosives. Uses of major importance but demanding smaller quantities of sulphur than those mentioned include the preparation of fine chemicals for medical and surgical purposes, and for vulcanizing rubber to be used in a multitude of forms varying from heavy duty tires to fine toilet articles. On the whole, virtually all fields of industrial endeavor, as well as all phases of everyday living in the progressive countries of the world, are the beneficiaries of products made possible indirectly by the use of sulphur and its compounds.

Production of sulphur. During the period 1911-1915 the average annual world production of native sulphur was only about 800,000 metric tons, whereas in recent years the average has exceeded 3½ million metric tons per year, an increase of 350 per cent in about three decades. Italy was for many years the world's leading sulphur-producing country, but since 1913 the United States has held first place (see Illus. below). In recent years the United States has produced 85 to 88 per cent of the world's total; Italy, in second place, has furnished 10 to 12 per cent.



Sulphur. Production of the United States and Sicily since 1910 Since these are the chief sources of sulphur, the dominant position of the United States is clearly evident

Sulphur in the United States. The production of native sulphur in the United States ordinarily exceeds three million tons per year, more than 98 per cent of which is represented by the output of companies operating in the Gulf Coast deposits of Texas and Louisiana. Prior to the turn of the century, sulphur was discovered in association with the salt domes of the Gulf Coast, but because of the unconsolidated sediments beneath which it was found, mining by the shaft method proved impracticable and exploitation was delayed because of lack of means of getting at the sulphur.

This handicap was overcome by Dr. Frasch, a chemist formerly associated with the petroleum industry, who devised a method whereby the sulphur could be melted and forced out of wells by water pressure. The method involves sinking a triple pipe system, a large pipe outside with smaller ones inside, by drilling methods through the upper rock layers into the porous rock, usually limestone, impregnated with sulphur. The sulphur is melted by injecting superheated water through the outside pipe. Then the molten sulphur, which is heavier than water, flows into a small pit known as a *sump*, at the

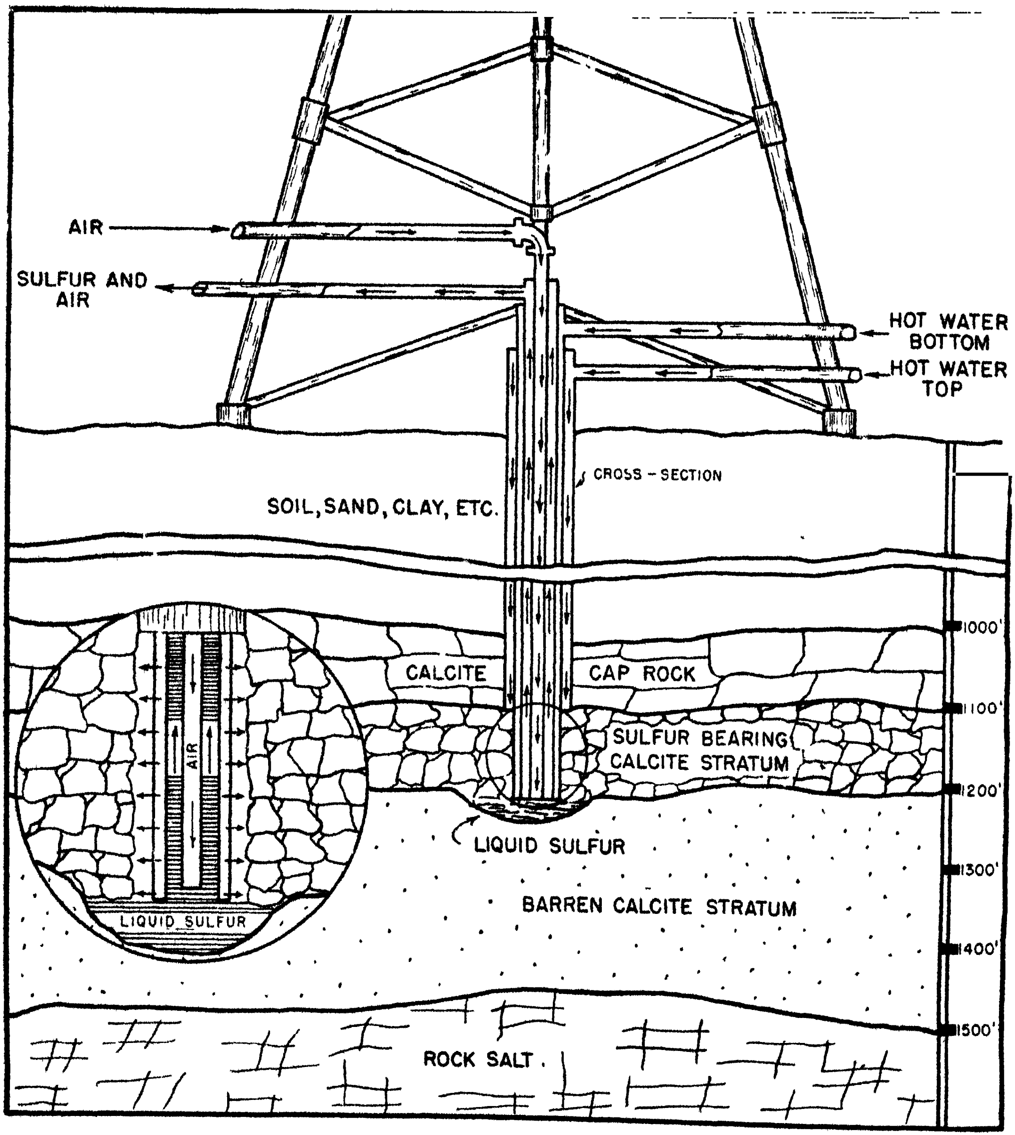


Diagram to illustrate the essential features of the Frasch process of mining sulphur. Note carefully the concentric arrangement of pipes and the purposes served. The circular drawing at the lower left is an enlarged bottom hole to give the details. It should be added that the molten sulphur is forced out by air and steam pressure indicated by lower vent at left side of the derrick.

lower end of the pipe, whence it is forced by pressure of pre-heated air to rise in liquid form through the inside pipe (see Illus. p. 316). Thus it reaches the surface, where it cools into pure solid sulphur. The part of this operation which was difficult to perfect, and which required much experimentation, was that of keeping the temperature range of the water and of the molten sulphur within rather narrow limits. Sulphur melts at temperatures varying from 238°F. to 240°F. and in that form is a thin, light-yellow liquid. If heated beyond that figure, for example to 480°F. or 500°F., it becomes so viscous that it cannot be forced out by water pressure. To retain the narrow temperature range through a pipe system that in many cases extends down more than a thousand feet, demanded a high degree of control of heating and cooling; however, when the difficulty was overcome, this method of obtaining sulphur proved by far the most practical thus far devised.

Because of the low cost of exploitation of the large deposits found in the coastal plains southwest of Galveston, the state of Texas has been producing more than 75 per cent of the country's total and probably will continue to hold first place in the production of sulphur in the United States.

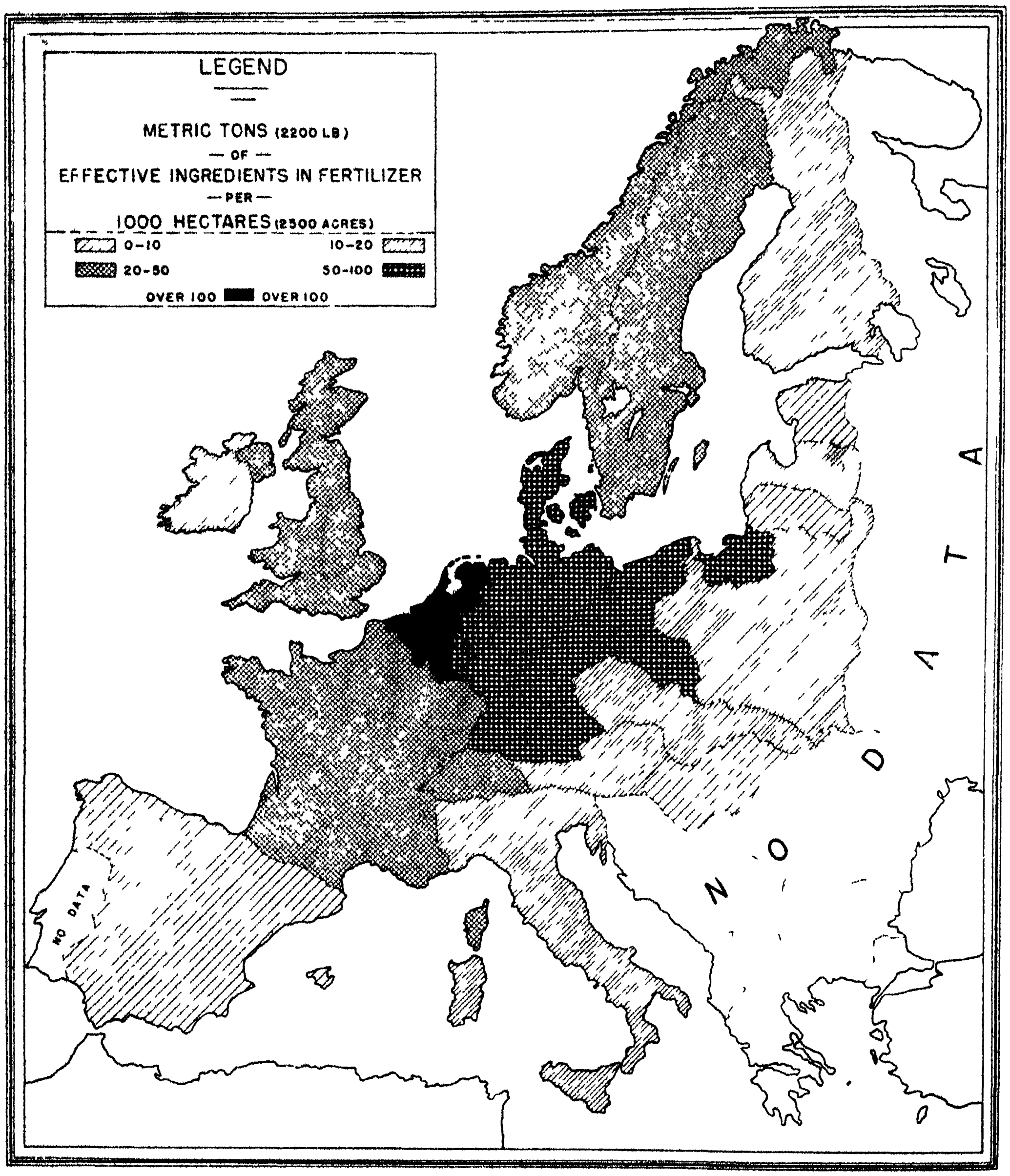
American exports of sulphur have increased greatly since 1920, and the United States now ordinarily exports more than 25 per cent of its output. The leading markets are in Canada, the United Kingdom, Australia, France, the Netherlands, and Germany. Because of their extensive proved reserves, Texas and Louisiana will probably maintain the high position of the United States in the world's production of sulphur (Illus. p. 315).

Sulphur in Italy. The island of Sicily is Italy's most important sulphur-producing center. For many years it was the world's foremost source of raw sulphur. The Italian industry has been hard hit by the exploitation of the deposits in the United States and the resulting competition that the American production has furnished in the world's markets. The principal foreign markets for the Italian sulphur are in the Mediterranean lands, Central Europe, and Russia. Inasmuch as it is known that Russia has large quantities of sulphur within her own domain, it is probable that the development now going on will make that country more than self-sufficient in this essential chemical element. There seems little chance, therefore, that Sicily will again assume the importance in the world trade that it formerly held. However, with improved methods of production and the expansion of chemical industries of neighboring countries, her present position will probably be maintained.

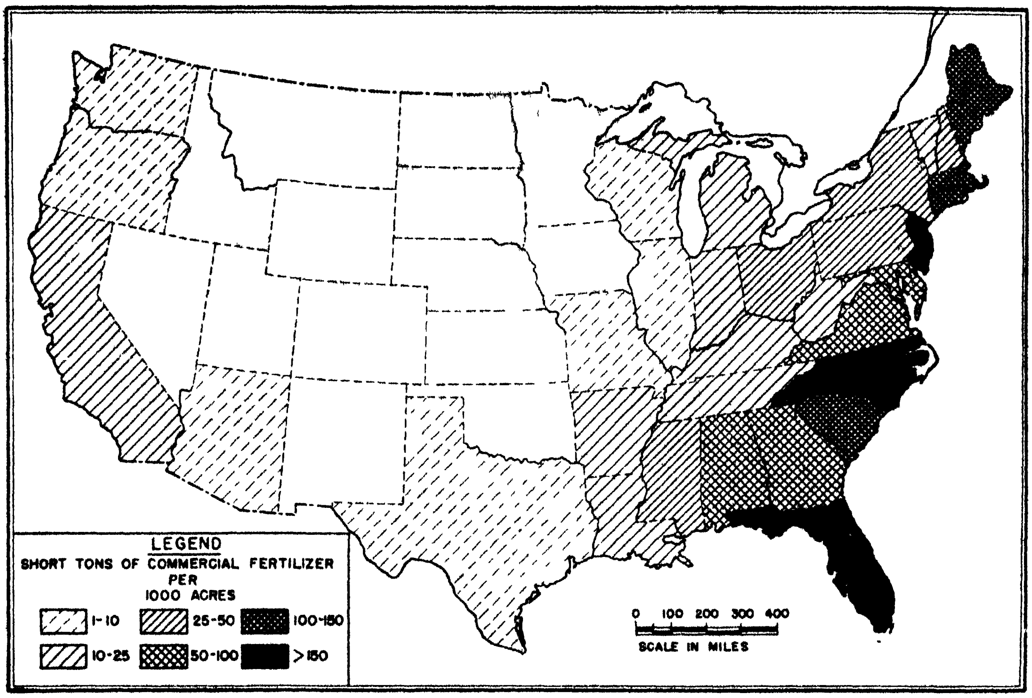
Commercial Mineral Fertilizers

Phosphates, nitrates, and potash are the chief ingredients of most of the various mixtures referred to as commercial mineral fertilizers. In many regions of the world the application of mineral fertilizers is necessary for successful agriculture. It may be said that the great milestones in agricultural progress are marked by the initiation of the following four methods of increasing crop yields: (1) the introduction of grasses, especially clovers and other legumes, into the crop system; (2) the plowing under of green crops such as peas, clovers, and other legumes, all broadly included under the general term of *green manures;* (3) the utilization of root crops, such as mangels, turnips, and beets, thereby breaking up the practice of continued grain farming on the same plot of ground, and at the same time improving the physical condition of the soil; and (4) the scientific application of mineral fertilizers. In many agricultural districts, the last-named practice has become general as a result of the chemical study of soils, first undertaken seriously about 1860 in Europe.

During the Middle Ages and later, students of population and food supply expressed alarm because of the declining productivity of the soil. Lands in the Mediterranean countries were producing only five or six bushels of grain per acre and productivity was steadily declining on other lands long in use. The lower Nile Valley was an exception, because of its recurrent floods and the attendant replenishment of soil fertility; these caused productivity to remain high and made of that region a rich granary, greatly desired by the various Mediterranean powers. In Britain a yield of ten to twelve bushels of wheat per acre was considered to be good. The farmers of the time found it increasingly difficult to maintain the crop yields of the land, and this, in the face of increasing population, gave



Map of consumption of commercial fertilizers in northwestern Europe If data were shown on local rather than national scale, the southern parts of Sweden and Norway would be indicated as heavy consumers rise to a growing fear of famine. Production was being maintained largely by clearing new lands and making use of virgin soils. As the areas of such lands were declining, serious-minded students began to fear that the day of exhaustion of the soil was rapidly approaching and that the time would soon come when the population of the world would be suffering from malnutrition and later be subjected to starvation. Under these conditions there is little wonder that people began to think of the world as growing old. *Old* connotes waning power and lessened productivity.



Use of commercial fertilizers in the United States. Some commercial fertilizers are used even in the states shown blank, but on a state-wide basis, percentage is still low, although known to be increasing

In many countries, productivity of the soil has been radically changed during the past few centuries. England now averages about thirty bushels of wheat to the acre. Denmark, southern Scandinavia, and the adjacent lowlands of Germany and the Netherlands produce average yields of thirty to forty bushels per acre, although the land has been tilled for centuries. The specter of want has been routed, and the world now gives promise not only of greater production but also of more prolonged production than seemed possible to students of earlier times. Thus, the achievements of agricultural science have given us a world of renewed youth in which to live. This accomplishment is of course the result of several factors, such as improved methods of tillage, crop adaptation, and the introduction of new improved varieties; but in the whole scheme the use of mineral fertilizers has played an important part.

In Europe the consumption of commercial fertilizer reaches its highest point in the Netherlands, Denmark, and Germany. (See Illus. p. 318, Map of Europe.) However, if the amount of fertilizers used could be limited to specific areas where applied instead of to the entire country as shown on the map, we would find that the same degree of intensity applies to southern Sweden, southern Norway, eastern England,

and northeastern France. All these comprise an area where yields per acre are highest, and this is largely a response to the heavy applications of fertilizers and barnyard manures. It is quite true that fertilizers are expensive, but the added expense is more than compensated if good markets are available and the pressure of population on the land is heavy.

Commercial fertilizers in the United States. The fertilizer industry has become one of the large industries of the country and one of growing importance to the success of agriculture in many sections. The output of American fertilizer plants has increased from less than 3 million tons in 1899 to more than 10 million tons at present, an increase of nearly 250 per cent. The industry, with respect to both production and consumption, is developed most extensively in the eastern parts of the country, throughout the states from Maine to Florida, although in the aggregate the heaviest use is in the southeast. There the population is dense, much of the land has been farmed a long time, rainfall is heaviest, temperatures are relatively high, and thus the soils have been leached most severely. The eastern states, which comprise about one-fifth of the nation's land area and farm acreage, contain about 80 per cent of the fertilizer plants, produce more than 80 per cent of the output, and account for 80 to 85 per cent of the consumption of commercial fertilizers in this country. In recent years, however, the use of fertilizers has been intensified in the Pacific Coast states and has even been extended into the prairie states of the Missouri Valley. This is especially true where irrigation has been introduced and where for many years large yields were obtained from the native soils without the use of commercial fertilizers. It has now been found that on these irrigated lands productivity per acre, which has been slowly declining, can be economically increased by the proper application of fertilizers (see Illus. p. 319).

The fertilizer industry of the United States is dependent upon foreign countries for part of its raw material, but not to the extent that was true a quarter of a century ago. The value of imports declined from a yearly average of 57 million dollars in 1921-1925 to an average of only 35 million dollars in 1935-1939. The decline is attributed to the discovery and exploitation of potash salts, particularly in New Mexico and the adjacent portion of Texas, and to the erection of nitrogen fixation plants in this country thus reducing the imports from Chile.

Fertilizers may be applied separately, and many agriculturists prefer to purchase the several ingredients and to prepare mixtures in accord with what they believe to be the needs of the particular fields to be tilled. Others, however, prefer to buy ready-mixed fertilizers prepared according to formulae worked out by soil students and farm managers to fit the general needs of soils in particular communities. According to the latest data available, about 50 per cent of the fertilizer used by the farmers of the United States is purchased in ready-mixed form, commonly known as commercial fertilizers; the remaining 50 per cent consists of materials which may be applied separately, mixed by the farmers themselves. The mixed fertilizers are usually designated by numerical symbols which refer to the three essential ingredients, namely, nitrates, phosphates, and potash. Thus, "3-8-4" is a fertilizer which has a plant food content of 3 pounds of nitrates, 8 of phosphates, and 4 of potash in each 100 pounds of the fertilizer as purchased. The remaining 85 pounds consist of carriers, generally materials which have a beneficial action on the soil. Some form of lime is ordinarily the chief constituent of this carrier material.

Principal kinds of commercial fertilizers: 1. NITRATES. Nitrogen is the most expensive of the fertilizer materials. It is the chief constituent of the air, the supply in nature being inexhaustible, but it may be obtained indirectly from other sources as well. Heavy expense is involved in extracting the nitrogen from the air, or from other sources, and converting it into a form fit for plant food or industrial purposes.

The indirect sources of nitrogen include, for example, dried blood and tankage from packing plants, fish scraps, dried crabs, and other fish refuse. The use of fish as fertilizer is still practiced extensively in parts of Japan and in coastal areas of the Old World where fish are plentiful and land is scarce. This is a practice of long standing in the New World as well. It is claimed that the Indians showed the first settlers of Plymouth, Massachusetts, how to produce Indian corn by placing a fish with every hill of seed.

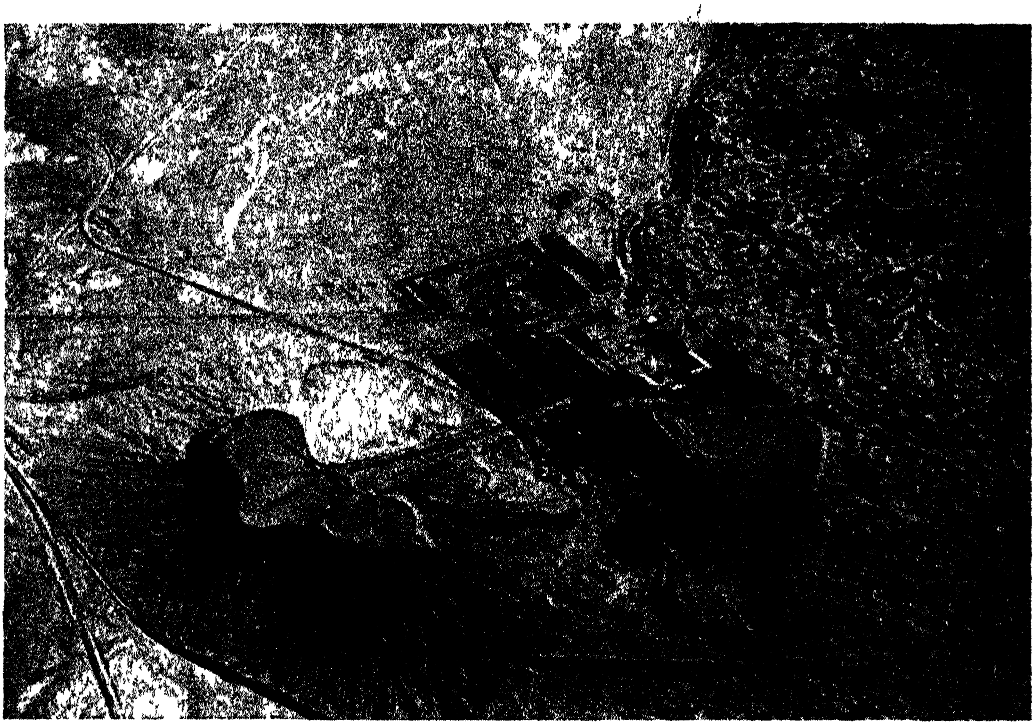


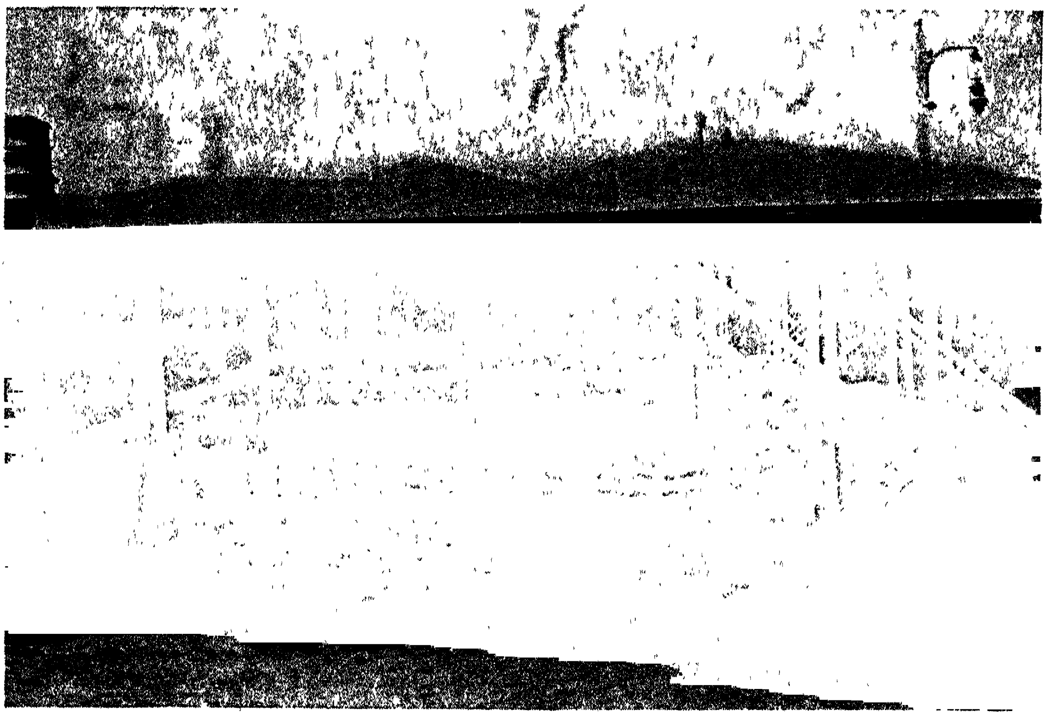
Photo by John L. Rich, American Geological Society

Nitrate. Nitrate plant in a *salar*, or dried up lake, 32 miles northeast of Iquique, Chile. At the right is the pitted surface from which the *caliche* (nitrate ore) has been dug, in the center is the processing plant where the nitrate is extracted from the earthy *caliche*, to the left is the main dump where the refuse is deposited on the smooth floor of the *salar*.

Native prairies, particularly in the interior of the Middle West, were characterized by a grassy vegetation interspersed with numerous legumes. These legumes contributed greatly to the high fertility of the soils of the prairies when these were first placed under cultivation. The example thus set by Nature is now emulated by man through the introduction of legumes into rotation systems of farming in order to replenish the nitrogen lost through continuous cropping. The soil is enriched by nitrogen fixation caused by the activities of bacteria in connection with the root systems, while at the same time the legumes themselves can be harvested and used for feed, or, where additional organic matter is needed in the soil, they can be plowed under to serve as green manure.

Commercial fertilizers, however, either make use of nitrate obtained through fixation from the air by means of chemical processes or of nitrates obtained from desert areas where the mineral nitrate has accumulated as a result of evaporation of waters under arid conditions. Mineral nitrate is a product of the desert. Although small quantities have been produced in Death Valley, California, and in some other desert areas, from a commercial point of view Chile has long been the world's only important source of supply. The practically rainless desert of northern Chile, which is located between the lofty peaks of the Andes and the Pacific Coast, has been found to contain the world's greatest store of mineral nitrates. These deposits of soluble nitrate of soda have been slowly concentrated there through the ages, and man's exploitation is likely to be a harvest of short duration in comparison with the period of accumulation. The mining methods are relatively simple. The cover of a few feet of non-nitrogen-bearing materials is removed by steam shovels, and below it is found the relatively soft nitrate ore, known as *caliche.* This material is loaded by steam shovels into cars and hauled to the refining plants, where the nitrate is dissolved by hot water, thus separating it from the insoluble, earthy material. The solution is then evaporated to dryness and the nitrates precipitated as salts in a manner similar to that used in precipitating sugar from cane or sugar-beet juice (see Illus. p. 321).

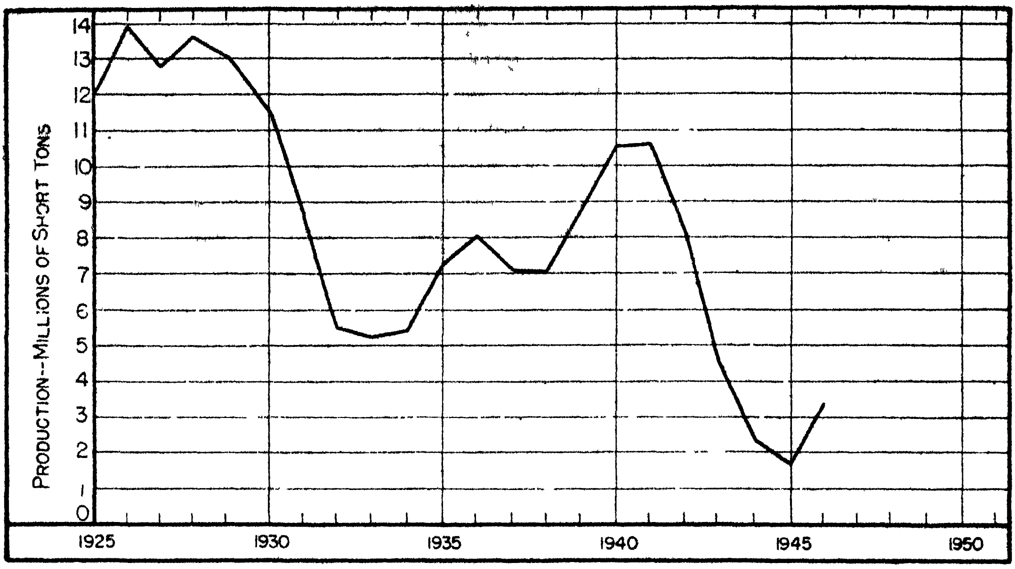
Historical sketch of the development of Chilean nitrate. Commercial exploitation of the Chilean deposits began in 1830, but not until the late 1870's had large production been attained. The deposits then had been developed largely by Chileans, although the nitrate fields were in lands belonging to Peru and Bolivia. The War of 1879-1882, between Chile on one side and Peru and Bolivia on the other, ended in a decided victory for Chile; as a result, Bolivia and Peru had to give up their nitrate lands and Chile became master of the world's greatest nitrate deposits, receiving what proved to be a colossal indemnity.



Courtesy Chilean Nitrate Educational Bureau, New York.

Nitrate. Bagged nitrate ready for shipment This is the "end product" of the type of processing plant shown in the previous illustration

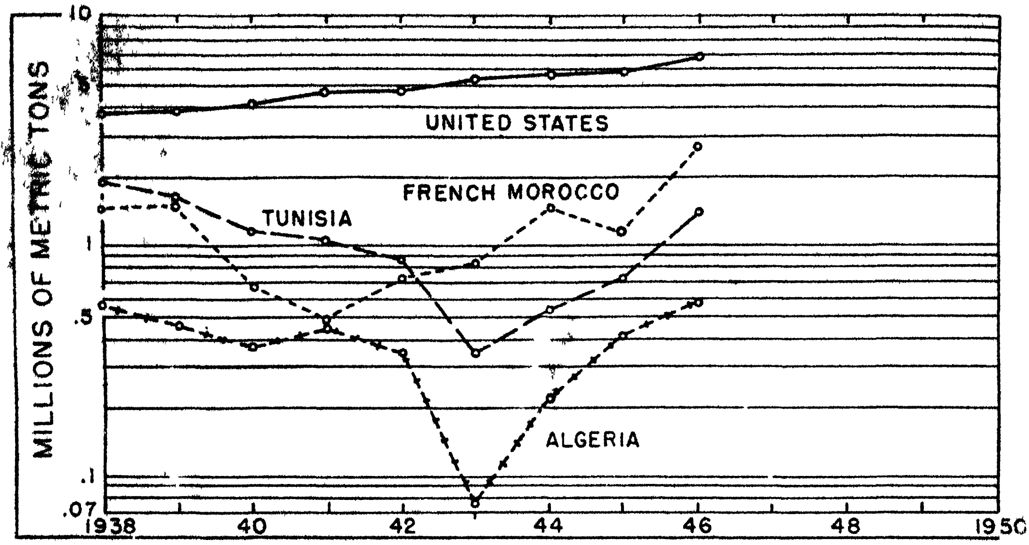
The nitrate industry of Chile ordinarily employs over 40,000 men. It has transformed a barren desert into an area of industrial activity. It has stimulated the growth of coastal towns and railroad facilities and through export taxes has contributed much to the nation's income. In earlier years the export tax on nitrate contributed as much as 80 per cent of the nation's revenue. Taltal, Antofagasta, Tocopilla, and Iquique are the best-known shipping ports. Much of this industrial glory is facing a questionable future because of the expanding output of synthetic nitrogen in the United States and Europe. Although the percentage of the world's nitrate provided by Chile has steadily declined, the actual exports, while subject to violent oscillations as a result of war conditions, have also declined (see Illus. above).



Nitrate. Annual exports of Chile since 1880. When was the peak of exports reached? What reason can be given for the serious decline shown between 1930 and 1935? What factors were important in 1941-1945? Downward trend resumed in 1947 and 1948, exports below 2 million tons.

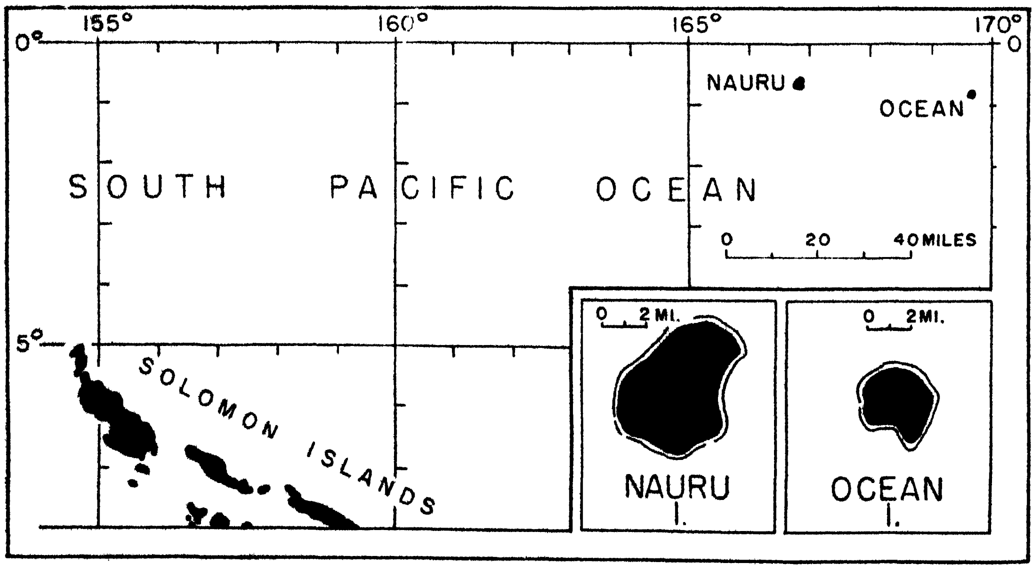
International trade. As indicated in the graph, the exports of nitrate from Chile have shown wide variations, a condition which is not conducive to steady prosperity. The United States has provided a market which has taken 40 to 50 per cent of the Chilean output, and it is probable that, despite the increasing expansion of synthetic nitrogen production in this country, Chile's exports will remain quite important because of the low-cost ocean transportation from Chile to the eastern markets of this country. In the past, the Old World purchased large quantities of Chilean nitrate, but in recent years this market has almost vanished. The rapid development of processes for making artificial nitrates at steadily decreasing costs in American and European countries has caused Chile to lose her monopolistic position in the world's nitrate industry. In 1885 she produced nearly 85 per cent of the world's nitrogen requirements, but she has now been reduced to a position of meeting less than 10 per cent of the world's demand. However, even though the prominence of Chile has been lost forever, all indications point to the continued exploitation of the deposits, and Chilean nitrate will continue to be an important resource for use not only in normal times but particularly in emergencies of world-wide scope.

2. **Phosphate rock.** Rock phosphates are chiefly phosphates of lime, and although their foremost value as fertilizers depends

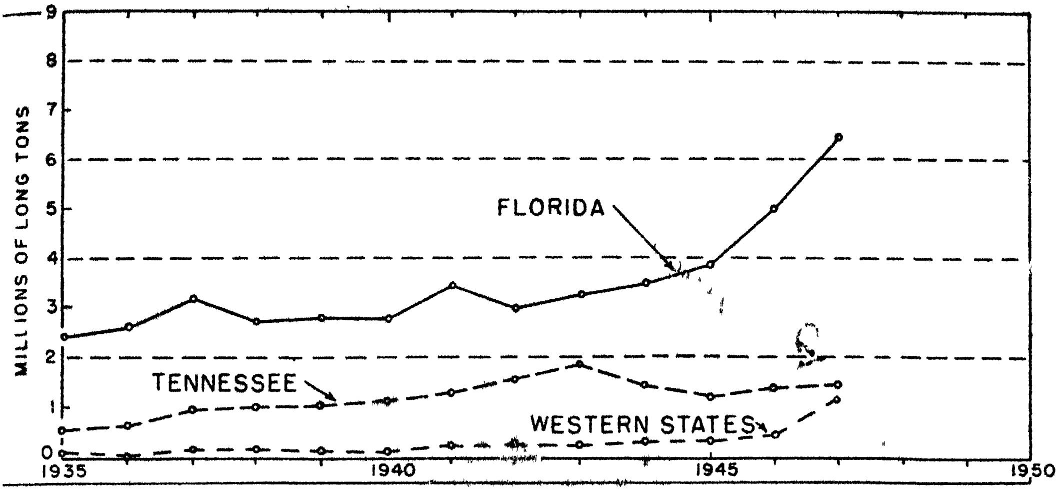


(A.) Phosphates. Semi-logarithmic drawing. Annual production of phosphate rock, principal countries since 1938. In terms of totals how did the United States rank with the combined production of the North African countries in 1946?

on their phosphorus content, most soils that need phosphorus also need lime. In addition to their importance as fertilizers, the phosphates constitute the raw material for a number of industrial products, and therefore, like salt, sulphur, and nitrates, they are also of great importance in the chemical industries. The United States has consistently been the principal producer of phosphates during the present century. The countries of northern Africa taken collectively constitute the major competitive region outside the United States, and in some years their combined production has exceeded that of this country (see Illus. above). In Africa, Tunisia has been the

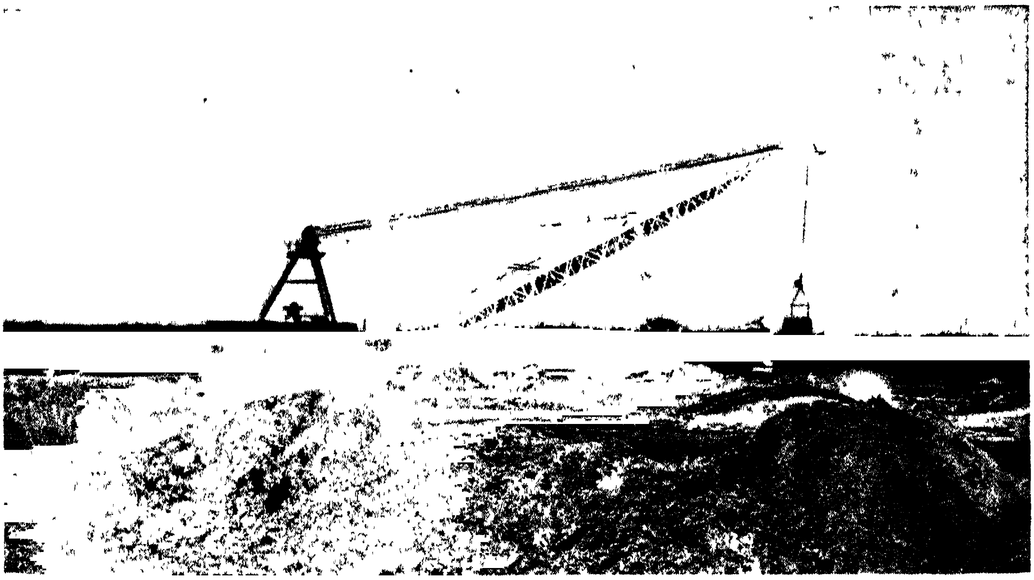


(B.) Phosphates. Map of Nauru and Ocean Islands to show location in the South Pacific.



(A) Phosphates. Graph to show trend of production of phosphate in principal states since 1935. What is significant in the sharp upward trend shown by the western states since 1945?

leading country for a number of years, but the continuing trend favors French Morocco for leadership in that area. The principal producing centers, aside from the United States and North Africa, are the islands of the South Pacific, particularly Nauru and Ocean Island west of the Gilbert Islands. During the years preceding World War II, the United States and North Africa each produced approximately 40 per cent of the world's supply, with the remaining 20 per cent being widely distributed among numerous countries and islands, but with Nauru and Ocean Island contributing about 10 per cent of the world total. War conditions reduced production in areas outside



Courtesy Coronet Phosphate Company, Plant City, Florida.

(B) Phosphates Dragline feeding phosphate matrix to sump on ground surface where it is subject to washing the United States in marked degree, thus causing a decline in world production. During the same period, however, the trend was distinctly upward in the United States, causing this country to produce nearly 60 per cent of the recorded world output (see Illus. p. 327).

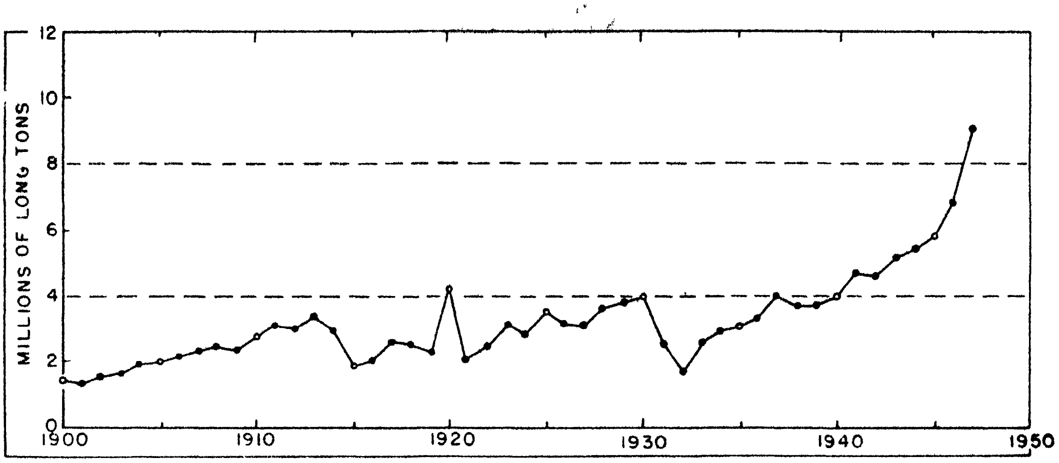
Phosphate rock in the United States. While phosphate rock is known to exist in a number of states, commercial production is limited to relatively few. Florida has long held undisputed supremacy in the output of phosphate rock, a position which she still holds, being credited with 67 to 72 per cent of the nation's total (see Illus. A, p. 325). Tennessee, as may be noted from the graph, holds second place and has shown a marked increase since 1935. The western states, Utah, Idaho, Montana, and Wyoming, until 1935 had been producing small quantities, but at that time they began an upward trend which was somewhat erratic and slow until 1947, when production was more than double what it had been in any preceding year.

Courtesy Coronet Phosphate Company, Plant City, Florida.

Phosphates. Processing plant where phosphate rock is treated to make it usable as mineral supplement in foodstuffs. Note long, rotary kiln in which the crude phosphate is heated as part of the concentration process in preparation of phosphate for agricultural or industrial uses.

Phosphate production in Florida is favored by low cost of mining, huge reserves, nearness to domestic markets, and ocean transportation to foreign markets. The rock phosphate occurs either as a solid ledge known as "hard rock" or as an unconsolidated thick layer known as "pebble rock," which is overlain by a comparatively thin overburden, readily removable by steam shovels. The pebble-rock layer is so friable as to make low-cost hydraulic mining possible (see Illus. B, p. 325 and above).

The increasing importance of intensive agriculture in the Pacific Coast states has given rise to important markets for phosphates, and this, together with increasing demands for commercial fertilizers within the Mississippi Valley area, has induced exploitation in the western part of the United States, where extensive deposits of phosphate rock have for some time been known to exist. In Utah, Idaho, Montana, and Wyoming large reserves of phosphate rock have been mapped, thus giving assurance of unfailing supplies for many decades to come. The most recent trend of production indicates that this western center may readily reach high importance and in time equal phosphate production of Florida and Tennessee (see Illus. A, p. 325).



Phosphates. Marketed production of domestic phosphate rock in the United States since 1900. Note pronounced rise since 1940.

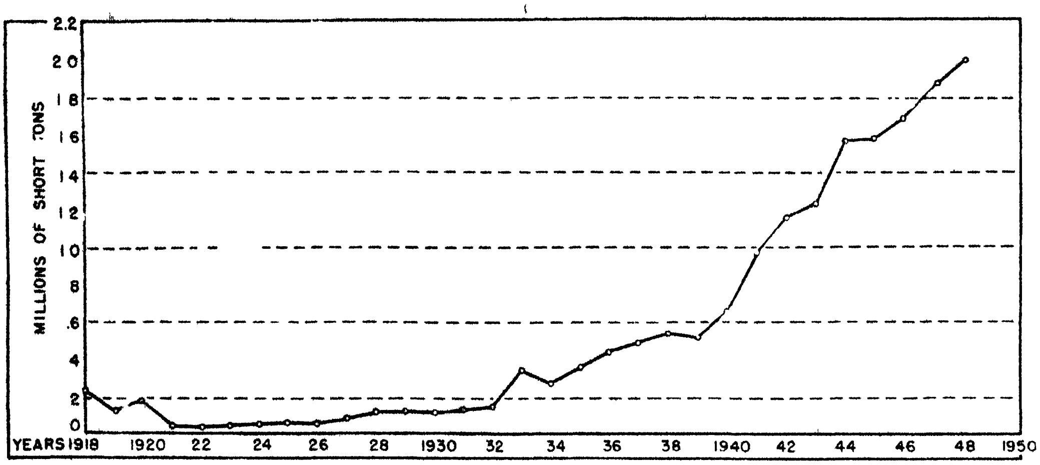
The steady rise in the apparent consumption of phosphates in the United States is clearly shown on graph above. This rise has been most conspicuous during the past decade: in 1937 the apparent consumption was approximately 2,900,000 long tons and in 1947 it had reached 7,400,000 long tons. The increasing importance of the western states in this expansion is indicated by the fact that they produced only 3.3 per cent of the smaller total in 1937, compared with 13.1 per cent of the larger total of 1947.

Large quantities of phosphate rock are exported by the United States every year. During the five-year period ending in 1939, the average annual exports slightly exceeded 1,100,000 long tons; in 1947 our total exports reached 1,685,000 long tons. Europe is and consistently has been the most important customer, but in recent years Canada has become one of the leading markets. During the period immediately preceding World War II, Japan was one of our greatest foreign markets. This trade of course was disrupted by war conditions, but it seems probable that the necessity for high crop yields in order to support the dense population is so great that Japan will reach its former market status within a short time.

In the United States, all indications point to the continued importance of phosphate rock as a raw material for the manufacture of commercial fertilizers and for use in industry. The trend now in progress will undoubtedly continue because reserves are large, and the demands are increasing because of pressure upon the land for added production, a factor still further augmented by the steadily increasing population of the United States. In the export markets, competition from North Africa and from the South Sea Islands is likely to increase, and supplies from those sources may reduce the percentage of American sales in the Mediterranean lands and in southern Asia.

3. Potash. Potash is a term applied to

salt-like materials wherein the element *potassium* (Kalium) is the essential ingredient. Statistically, it is usually given in one of two designations—*crude potash* or *potassium oxide*. By custom, and irrespective of the form and degree of purity, the content is expressed in terms of equivalent potassium oxide (K_2O), a compound never found in nature. Practically all of the world's supply of potash is obtained by mining various sedimentary rocks, such as those in central Germany and in the Carlsbad district of New Mexico, and by treating natural brines, as at Searles Lake, California, and Bonneville, Utah.



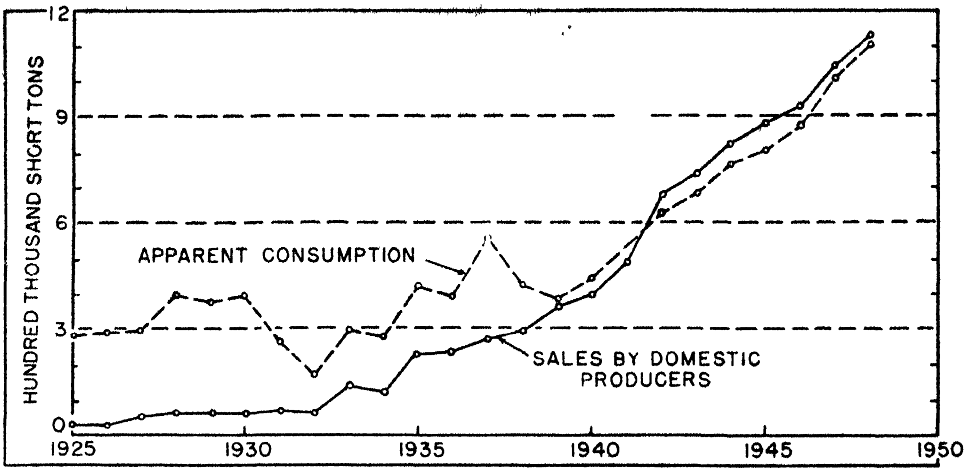
Potash. Production of crude potash in the United States annually since 1918. Note that the pronounced trend upward began about 1932-33. Content of potash, K_2O equivalent, was 55.2 per cent in 1946, and 53.3 per cent in 1948.

Potash is an important ingredient in chemical manufactures and is used in many industrial products such as chemicals, medicines, paints, paper, and bleaching agents. However, its greatest use is in agriculture, especially in Europe and in the New World, where it is indispensable if high yields are to be obtained. Justus von Liebig, a prominent German chemist, in 1850 discovered that potash compounds constitute essential plant foods in the soil which are not readily replenished by nature. Since continued cropping leads to serious depletion of available potash, this causes crop yields to decline. Von Liebig discovered also that productivity may be restored or increased by the application of suitable potash fertilizers. His discoveries are generally credited with marking the introduction of the scientific use of mineral fertilizers into agricultural practices.

Potash-bearing materials from which production is now obtained, and those which comprise possible sources, may be classified as follows: (1) Highly water-soluble minerals, either in the form of brines or as solid deposits in which the potash occurs. In general, the advantage of such minerals is that the ores do not require as elaborate treatment to condition them for use in fertilizers as do less soluble minerals. (2) Potash-bearing minerals, such as green sands and certain shales, in which the potash-containing constituent is insoluble but from which water-soluble potash can be produced by chemical treatment. (3) Sundry materials, such as the flue dust of Portland cement plants and blast furnaces, from which potash can be recovered as a by-product. (4) Miscellaneous materials that will yield potash, the most plentiful of which is sea water.

The first of these sources furnishes by far the larger part of present world production, but each of the others is of commercial importance in some places. Dust from flue gasses of cement and blast furnaces is increasingly important in the United States, but the major production in this country is obtained from the potash beds near Carlsbad, New Mexico, from the natural brines of Searles Lake, California, and from brines in Utah.

Potash in the United States. Prior to World War I, the United States was almost completely dependent upon Germany and France for its potash supplies. When war conditions cut off these sources, the scarcity of supplies led to record-breaking prices and the development of domestic sources.



Potash. Consumption and sales of potash on basis of equivalent potash content, K_2O, annually since 1925. Since what year has the United States produced potash in excess of its consumption? About what were the import needs in 1930?

Some of the alkali lakes of the western part of the sand hills of Nebraska, which had been proved to contain potash salts, attracted attention and experimentation. Commercial production began in 1915, and by 1918 Nebraska had become the major source for the domestic production of the much needed potash. However, since the brines had to be evaporated by means of expensive fuel and machinery, production costs were high. When the war was over, competition of European potash could not be met, and the end of the potash dreams of the ranchmen in the sand hills came almost as suddenly as the dreams themselves had begun.

Searles Lake, California, also came into potash production during World War I in connection with the emergency demands for potash, but because of the accessory minerals found in its brines, it was able to continue production under normal peacetime conditions.

The potash output of the United States has increased steadily since 1921. Successful commercial activity has been continued at Searles Lake, but at the present time the Carlsbad field of New Mexico is the scene of the most extensive mining operations and provides by far the major part of the production in this country. Since 1941, the United States has been producing annually a supply of potash greater than market conditions have demanded, and thus the nation has become an exporting instead of an importing country (see Illus. above and A on p. 330).

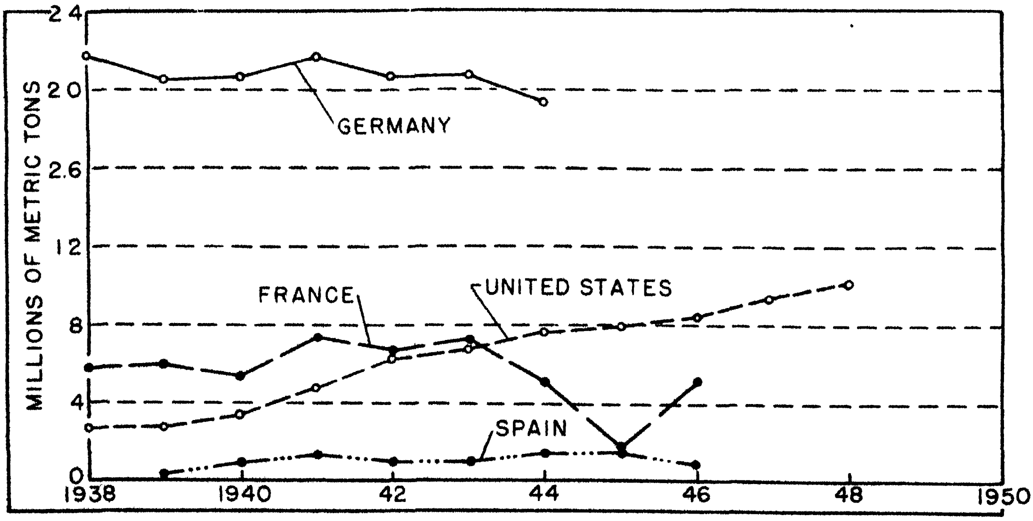
It should be understood at the outset that commercial potash is a product that must be processed to a greater or lesser degree from the original salts, because of the presence of impurities. The two principal uses of potash are (1) for fertilizer, the potash thus used being referred to as *agricultural potash,* and (2) for use in the chemical industries, where a high degree of purity is necessary, and known as *chemical potash.*

Courtesy Potash Company of America, Carlsbad, New Mexico.

(A) Potash. Processing plant near Carlsbad, New Mexico. Note size and equipment in use. Crude potash from the mines is here converted into forms for use in the fertilizer and chemical industries.

On the basis of the record for the five-year period, 1941-1945, inclusive, the average annual production of crude potash in the United States was 1,054,000 short tons, of which the potassium oxide equivalent averaged 730,400 short tons. Thus, on the basis of the record quoted, the K_2O equivalent was 69.3 per cent of the crude (see Illus. p. 328).

Extensive beds of potash salts have been found in New Mexico, with probable extensions into Texas. Other extensive potash-bearing formations have been found to occur under somewhat less favorable conditions in Wyoming and Utah. These, together with the known brines of the salt lakes in various parts of the United States, seem to make it certain that this country will



(B.) Potash. Production in principal countries annually since 1938, in tonnage based on reported K_2O content.

not again become dependent upon foreign sources of supply for this vital fertilizer and chemical raw material. Whether exports can be continued with increasing competition from European sources, particularly Germany, France, and the Soviet Union, may be debatable, but it now appears that American production can be profitably maintained to meet domestic demands and also to meet the needs of adjacent neighboring markets.

POTASH IN EUROPE. During the years prior to 1930, 90 per cent or more of the world's production of commercial potash was derived from the soluble potash salt deposits of Germany and France. The German deposits occur on the flanks of the Harz Mountains and extend northwest under the lowlands of Hanover and southwest into Thuringia; they underlie an area estimated to cover at least 25,000 square miles. The French deposits are in the upper Rhine Valley near Mulhouse, where the producing area has been estimated to include about 70 square miles. Estimates of the German potash reserves vary widely, but even the most conservative figures give assurance that at the present rate of consumption they will suffice to meet the potash demand for a thousand years or more. The deposits in France are estimated to be great enough to supply any probable demands for more than a century.

GERMAN AND FRENCH TRADE IN POTASH. The potash industries of Germany and France have supplied not only the great markets within their own borders but a large foreign market as well. The domestic markets have from the outset been due to the extensive use of agricultural potash, and more recently to the increasing importance of potash in the chemical industries. Among foreign customers, Britain and the low countries of northwestern Europe, from Belgium to Scandinavia, have provided the most important outlets. The Netherlands has long been using the most potash in proportion to area because of the intensive type of agriculture practiced and the potash deficiency of the soil.

Since World War I the international potash picture has changed, particularly because of developments in the Soviet Union and the United States. These two countries have ceased to be important markets for French and German potash and are now capable of surplus domestic production which will provide competition in international trade. The change was accelerated by the tendency of the European producers to organize cartels whereby prices were agreed upon and the markets divided among the producers so as to make possible sales at abnormally high figures. This practice induced other countries to seek deposits within their own borders and to experiment with new production and refining methods in order to promote domestic production for the protection of their own national interests.

THE GENERAL OUTLOOK FOR THE WORLD'S POTASH INDUSTRY. Let it be understood clearly that Germany has consistently been and still remains the world's foremost producer of potash salts. Her reserves are tremendous, mining conditions are favorable for large-scale output, and technological development seems to assure Germany's high position as a producer for countries outside her own borders during the foreseeable future. France likewise will probably continue to be one of the principal potash producers but will feel keenly the effects of competition from Germany and from other countries so far as her export markets are concerned. In recent years, large stores of potash salts have been discovered in Spain and in the Soviet Union, and both countries appear to be capable of exporting considerable quantities of potash during the years ahead. Russian output is increasing, and it appears probable that she has attained and possibly is exceeding the present output of potash in the United States; but Russia needs huge supplies of this fertilizer to meet her domestic needs. In the United States, while the known reserves are not so great as those of Germany, estimates indicate that they are great enough to meet the needs of this country for the foreseeable future. Development has proceeded with unexpected rapidity, and commercial development on a large scale has been attained in New Mexico, California, and Utah, with prospects for continued increase in this regard. The rapidly expanding demands in connection with American agriculture bespeaks an expanding market for all the essential ingredients of mineral fertilizers during the years ahead. Through scientific use of fertilizers, the productivity of the land can be increased with resultant increase in prosperity. The possibilities now known to exist surpass the dreams of the past; their achievement becomes the test of man's ability to use wisely the knowledge that has become available.

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Chapter Twenty

THE ECONOMIC SIGNIFICANCE OF POWER UTILIZATION

The ability of man to produce goods with increasing efficiency is the basis of the material welfare of the industrial nations today. With the increasing efficiency in the use of the sources of energy now known and being exploited, and with the additional possibilities that may come with sources of energy known but not now exploited, such as those of the tides, uranium, direct solar energy, perhaps even the energy of cosmic rays, we may expect the future to be marked by achievements of still greater industrial importance.

The earliest power resources. All the evidence now available upholds the idea that in prehistoric times women were the ones who domesticated plants and first tilled the soil with sticks or branches, stones, and bones, crudely fashioned into the predecessors of the modern hoe, spade, and rake. It seems probable that for doing work of this kind some animals more tractable than others were induced to pull boughs or branches over the newly spaded ground in order to prepare a better seedbed for the crops to be tended. Having thus found an animal which was tractable and perhaps even docile, it seems likely also that woman in her attempt to provide additional food for her offspring resorted to the milk supply of certain wild animals. She was thus led to take care of the young of such animals, to make friends with them, and to domesticate them. In some such manner, long before the dawn of recorded history, plants of value to man as foodstuffs were selected and animals were domesticated to serve directly as sources of food and of power to supplement muscular energy. Nevertheless, the extent to which man could use animals for this purpose was slight, and he continued to depend in large measure upon his own muscular energy to carry on the production processes necessary for his existence.

Human slaves as power resources. The necessity of supplemental power to create high standards of living for some served until quite recently as the basis for widespread systems of human slavery. In the wars of ancient and medieval times, the victors obtained from the ranks of the vanquished slaves to be used as household servants, hewers of wood, drawers of water, pullers of loads, and motive power for merchantmen and naval vessels. The production per slave was small, yet it was somewhat greater than was necessary to keep him alive and fit for work. The surplus production thus available aided in supplying the ruling classes with the luxuries which they demanded and in sustaining a leisure class essential for intellectual progress. The latter of course means a leisure class only in the sense that it is a class relieved of manual labor and earning its right to live through its cultural contributions.

During most of the historic past the bulk of the people toiled with low production per capita and but slight available surplus. As a result, they lived on a standard so low that today we would consider it to be submarginal, whereas the aristocracy with all its wealth and luxuries in many cases did not have the comforts that are available to most of the common people in the progressive nations of the present. This aristocracy, however, was largely instrumental in sponsoring the progress of the arts and sciences. The steady advancement of mankind in science and in the fine arts has been due in no small measure to the constructive accomplishments of the useful part of this class. "The Golden Age of Pericles" is often referred to as representative of man's highest intellectual achievements. Midst praise of this type, it is well to bear in mind that the term is a tribute to the achievement of part of the aristocracy of that day, that the great mass of the people were but little above the status of slaves, and that only a small percentage were participants in the comforts and enlightenment which now are extolled as representative of the period.

The pre-industrial era of colonial days in the New World. In order to picture clearly the tremendous progress which has been made in the past two centuries, it is helpful to give brief consideration to the industrial conditions which prevailed here and elsewhere during the period of British colonization in the New World. Manufactures were then almost entirely on a handicraft basis, and the equipment was simple indeed, as is shown by the fact that the shoe factories of those days were merely groups of cobblers in a large room.

In any new country where contacts with the outside world are slow and difficult, men turn first to agriculture because they must eat to live and they must farm for food. In the colonial days of North America this tendency was fostered further by ready markets for the agricultural products. Grain growing became dominant in Pennsylvania, Delaware, and the valley lands of New York, because the breadstuffs could be sold at a profit in New England and in the West Indies. New Jersey, because of her abundance of grasslands interspersed with fertile valley lands, became a grazing and cattle-feeding settlement. Virginia and her neighbor colonies early learned the art of cultivating tobacco, a native American plant, and held virtual monopoly in that field with profits so high as to justify imports of many lines of needed goods. Farther south the cultivation of rice and other grain crops and cotton became the principal pursuits. Under these conditions it was little wonder that manufacturing on a factory basis did not develop on a large scale south of the Hudson and that home-crafts were the dominant phase of the local industrial life.

In its agricultural aspects, New England was different from the colonies farther south. Because of shorter growing seasons, more rigorous winters, and less easily cleared soils, she could not compete in general agriculture with her neighbors. Local agricultural productivity was so low that the most arduous toil carried on with the simple tools of the day did not suffice to bring forth any surplus of foodstuffs. The chief product of the land available to the New Englanders for exchange was white pine, which was especially in demand as masts for the sailing vessels of the times. Since New England was thus handicapped in agricultural pursuits, and since she was favored by seaboard location, she found it advantageous to import staple foodstuffs rather than to depend solely on her own production.

Shipbuilding and commerce were favored by the forest resources and the protected waters of New England. Commerce led to manufacturing, particularly of such articles as were needed for equipment or supplies for ships. Iron manufactures became important, because even in the days of wooden ships much iron was needed for rods, bolts, and rivets. Massachusetts became the leading iron-manufacturing colony and remained so for more than a century prior to the War for Independence. Rope was needed by ships, and the impetus of this early industry is still reflected in the location of one of the largest rope factories of the United States at Plymouth, not far from the famous rock. Cooperage became a prosperous industry because of the timber readily available and the markets furnished by the demands for barrels to be used in ocean freightage. The demand for sailors' clothing led to the establishment of tailoring concerns in the seaports, and thus the foundation was laid for an important clothing industry. Manufactures which made use of imports of cheap raw materials constituted another phase of industry to which New England naturally turned. Illustrations are found in the crude sugar which was brought back from the West Indies and refined in New England for the domestic markets, and in the molasses which was obtained chiefly in the islands of tropical America, brought back to New England, and there distilled into rum—not a small item, when ships' allotments of rum for the sailors were deemed as important as the allotment for bread. Fish oils were sources of illuminants and lubricants, and therefore the refining of such oils became important. The preservation of fish depended almost entirely upon the use of salt, and so the manufacture of salt from ocean brines became an important industry in early New England.

For many of the activities mentioned in the preceding paragraph, power was needed, in fact it was absolutely necessary for a high degree of success. In this regard, New England was favored by numerous ponds and marshes out of which flowed streams characterized by comparatively uniform flowage and intercepted by low falls and rapids which could readily be controlled and the water directed against wheels. These mills, typical of the early water-power developments, were used to saw timber into lumber and to grind grain into grist. Before the day of huge dams and generation of electricity, they provided New England with a power resource that could be controlled and utilized to advantage under the competitive conditions of the times.

The diverging tendencies thus outlined characterized the industrial development of the colonial period in North America. Factories developed and prospered in New England, while agriculture, together with home crafts, dominated the colonies south of the Hudson. Whether the activities were of the so-called factory type or the home crafts, water-power plants were the only source of mechanical aid in doing the work. The ratio of human energy to the total energy expended was high and output per man was low. The inevitable result was of course long working hours and little surplus production. All who were able to do so toiled.

In England, however, more progress had been made in industrial development than was true in the New World prior to the close of the colonial period. Development in England had been particularly effective in the use of coal for steam engines, because the forest resources of that country had already been seriously depleted and water power was not so plentiful as in New England. This development had given the British quite an advantage in furnishing manufactured goods for continental Europe and the New World, and it had given rise to factory employment at higher wages than could ordinarily be obtained in agriculture in that country. Differentiation of industry had become pronounced because foodstuffs from the New World could readily be imported and the markets there were seeking manufactured goods in exchange for their exports of grains and other agricultural products. The Industrial Revolution therefore had already made considerable headway in England before the end of the eighteenth century, whereas it did not get under way in the New World until later.

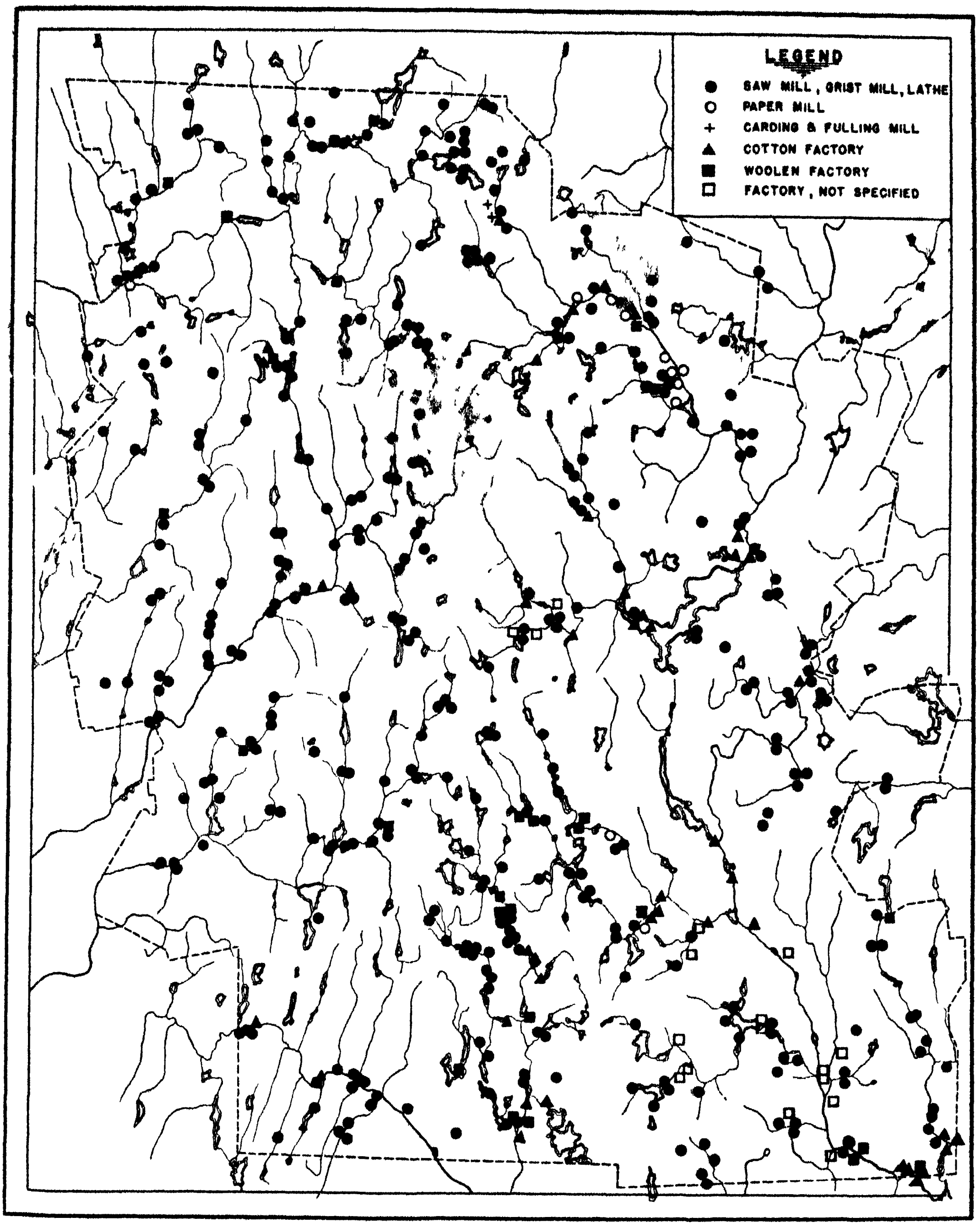
Industrial development in the United States: THE FIRST PERIOD—HANDICRAFT AND THE INTRODUCTION OF WATER POWER FACTO-

RIES, 1783-1840. During the Revolutionary War and in the years immediately following there was a great expansion of household manufactures among the people of the newly formed nation. Cut off from British supply, the colonists were compelled to make their own products. With labor scarce and high-priced, it was natural for them to turn to mechanical substitutes, and this proved to be a powerful impulse toward invention and improvements. After the war, factory development was hampered by the lack of capital and the immediate profits offered by investments in ocean shipping. Later, however, with trade restrictions put into effect, such as the Embargo Act of 1807 and the Non-Intercourse Acts of 1809, shipping declined and capital again began to seek investment in industrial enterprises. Thus, the shift of manufacturing from homes to factories and from hand labor to machines made but little progress in the New World until after the second war with Great Britain.

Before 1812 the cotton mills were small affairs limited for the most part to the spinning of yarn to be sold to hand weavers. The first complete cotton-goods factory in America was erected at Waltham, Massachusetts, in 1814, with a loom operated by water power. Soon after this, large mills were established along the lower course of the swift-flowing Merrimac, where large-scale water power could be created by the building of low dams, which were then the only feasible type, inasmuch as Portland cement had not yet come into use. These developments along the Merrimac gave impetus to the growth of a number of cities, among them Manchester, Lowell, and Lawrence. Since cotton manufactures did not require much skilled labor, they were among the first to be established on a large scale. Skilled male labor was scarce and high-priced, and no industry dependent upon it could survive the competition of the machine factories and the cheap labor of northwestern Europe. Young women who formerly had no means whereby they could become economically independent were soon attracted to the factories by the opportunity to earn a personal income or by the spirit of adventure. Widows and unmarried women, galled by being dependent upon male relatives for charity, hailed the factory as their liberator from a type of dependency which bordered upon economic slavery. New England thus presented a unique labor supply through her sailors' wives, unmarried women, and women of the farm, the last-named struggling against the hardships attendant upon trying to make a living upon poorly productive land.

Water-power plants could be installed at minimum cost along many of the streams of New England because of the numerous glacial lakes and swamps which provided natural reservoirs and assured constant stream flowage. The dams needed to enlarge these reservoirs could be constructed at comparatively low cost. Furthermore, the expansion of the factory idea came at a time when, for reasons already stated, the profits of seaborne commerce were declining and merchants were seeking other outlets for profitable investment of their capital (see Illus. p. 337). These various factors combined to give New England her early start in the cotton industry and elevated her to a position of supremacy which was maintained until after the beginning of the twentieth century.

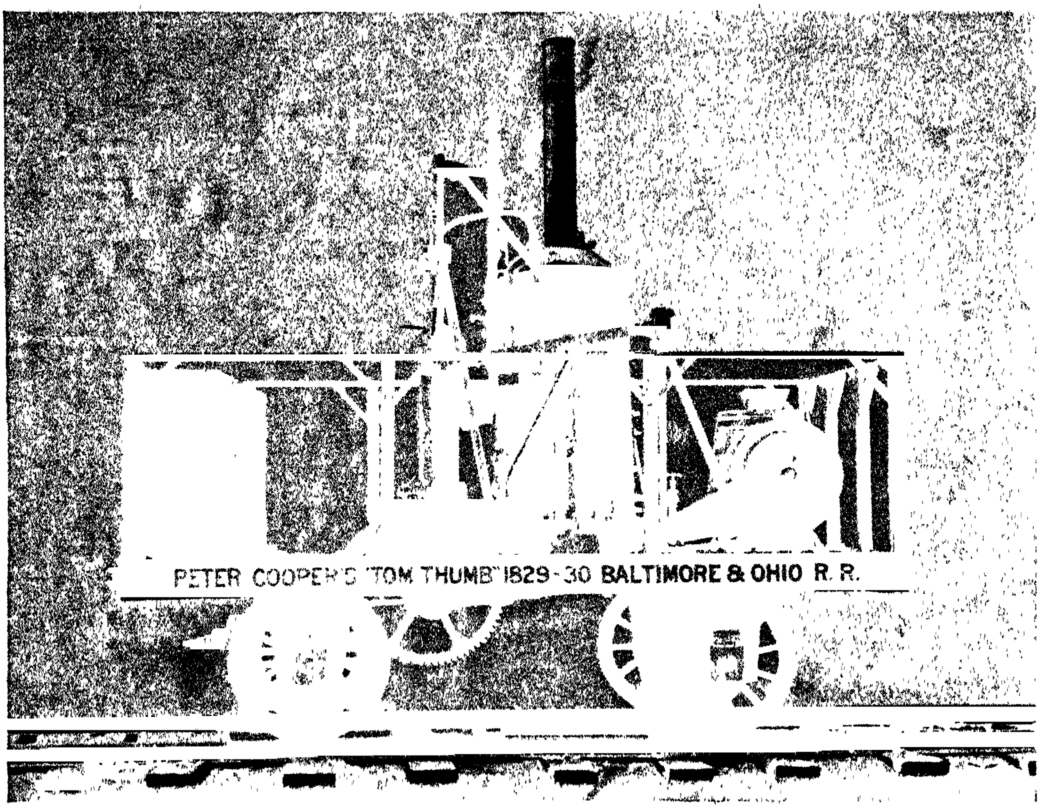
Although steam power had given great impetus to factory development in England, little progress was made in the New World until after 1815. Various factors were responsible for this retarded development; among them were (1) the abundance of land and the high returns from grain production, (2) the lack of available capital-seeking investment, and (3) the substantial profits of ocean and coast-wise shipping. Furthermore, European capitalists were not confident that the new nation had been established on a sound basis, because they knew that there were many in the United States during the Revolutionary War who had preferred the status of an English colony to that of an independent state. Credit therefore was almost wanting, and since steam-operated factories were com-



Map of water power plants in operation for mills and factories along the small streams of Worcester County, Massachusetts, in 1830. Note the numerous plants and their general distribution over the county. What must have been true of the relative sizes of the power plants and mills?

paratively costly to erect, development had to wait.

The result of the second war with Britain changed the political status of the United States from uncertainty to certainty. With political stability assured, European capitalists soon realized that the United States was a profitable field for investment, and consequently both cash and credit became available and the times right for rapid industrial progress.



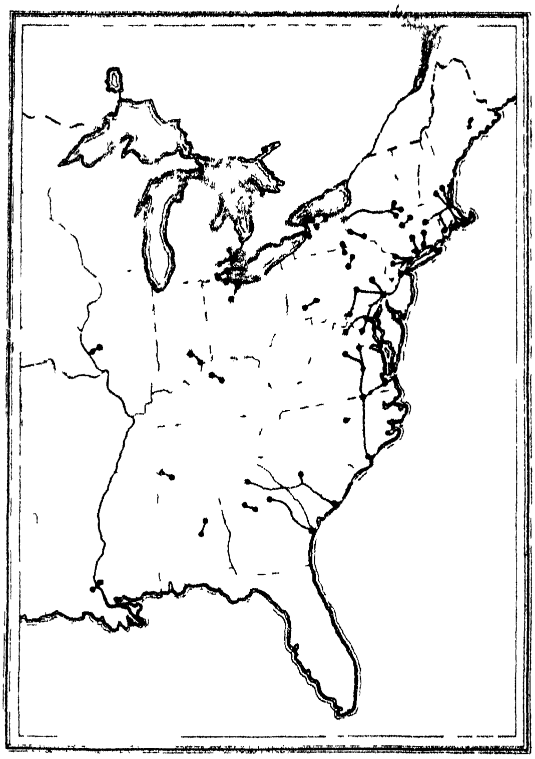
Courtesy Baltimore and Ohio Railroad.

First railway locomotive constructed in America. Built by Peter Cooper in 1829-1830. This crude type of locomotive was the pioneer. The decade following 1830 was one of great progress and thus initiated the railway age in America.

In the United States, steam had become successfully employed in stationary engines before 1830, with boilers fired with wood, however, rather than with coal. Water-power plants continued in operation, but they were beginning to be supplemented and later were displaced by steam engines. The beginning of the transition years was marked by the dominance of handicrafts and by simple factory equipment, while animals and small water power projects furnished the needed supplementary energy. Gradually, however, these activities gave way to steam power, with coal becoming the principal fuel. Machine methods had proved their merits and railroads were winning recognition as a new and greatly needed method of transportation. The latter years of the period brought the dawning of the steam age; its full light, however, did not appear until after 1840 (see Illus. above).

THE SECOND PERIOD—THE ASCENDANCY OF STEAM POWER, 1840-1860. Although prior to 1840 the manufacturing industries of the

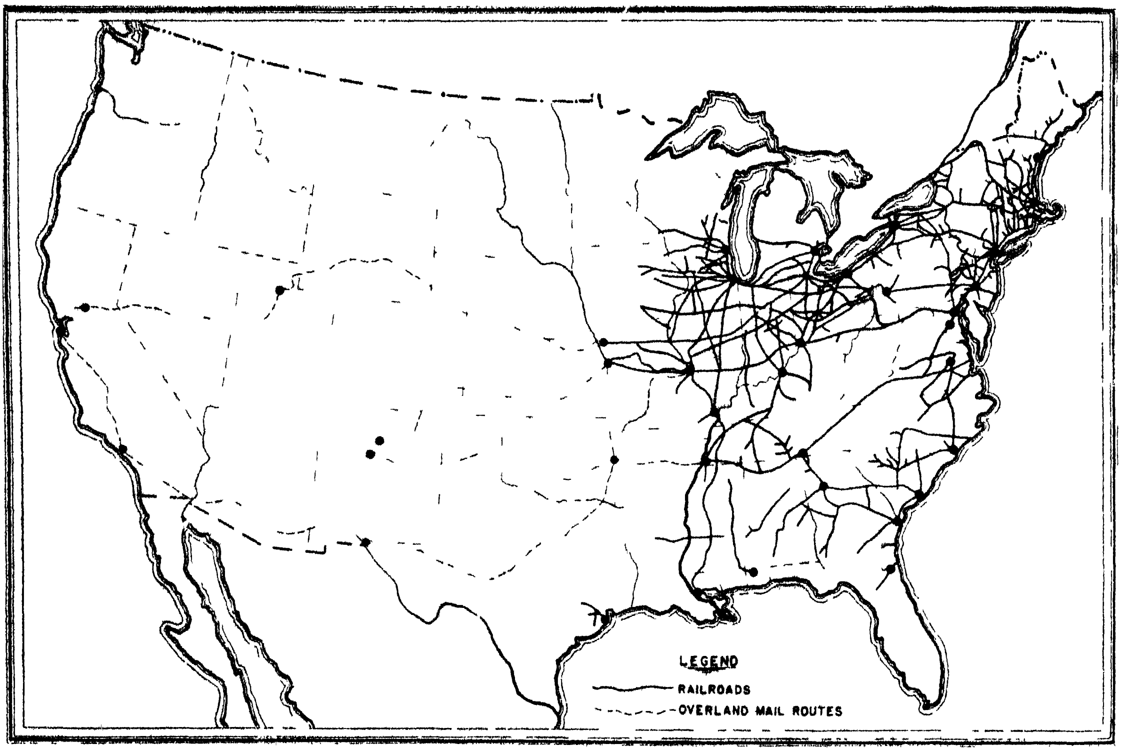
United States employed but a comparatively small percentage of the population, several of the major groups, particularly cotton, wool, leather, and iron, had become firmly established. The stationary steam engine had been developed into a practical power plant and the steam locomotive had won recognition as an efficient means of transportation. The following decades witnessed the greatest changes ever experienced in the operation of factories, in the building of railroads, and in the opening up of agricultural lands. This period marked the change from the water wheel to the coal-burning steam engine as the leading type of power plant. Railroads were built from the Atlantic seaboard to the heart of the Mississippi Valley (compare pages 339 and 340) and agricultural lands were thrown open for settlement from the Alleghenies to the Missouri River. More acres were put under the plow between 1840 and 1860 than in the three centuries preceding.



Railroads in operation in 1840. The earliest steam railroads served chiefly to connect local production centers with the water routes then used for the longer hauls to market. Adapted from C. O. Paullin and J. K. Wright, *Atlas of the Historical Geography of the United States*, American Geographic Society, New York.

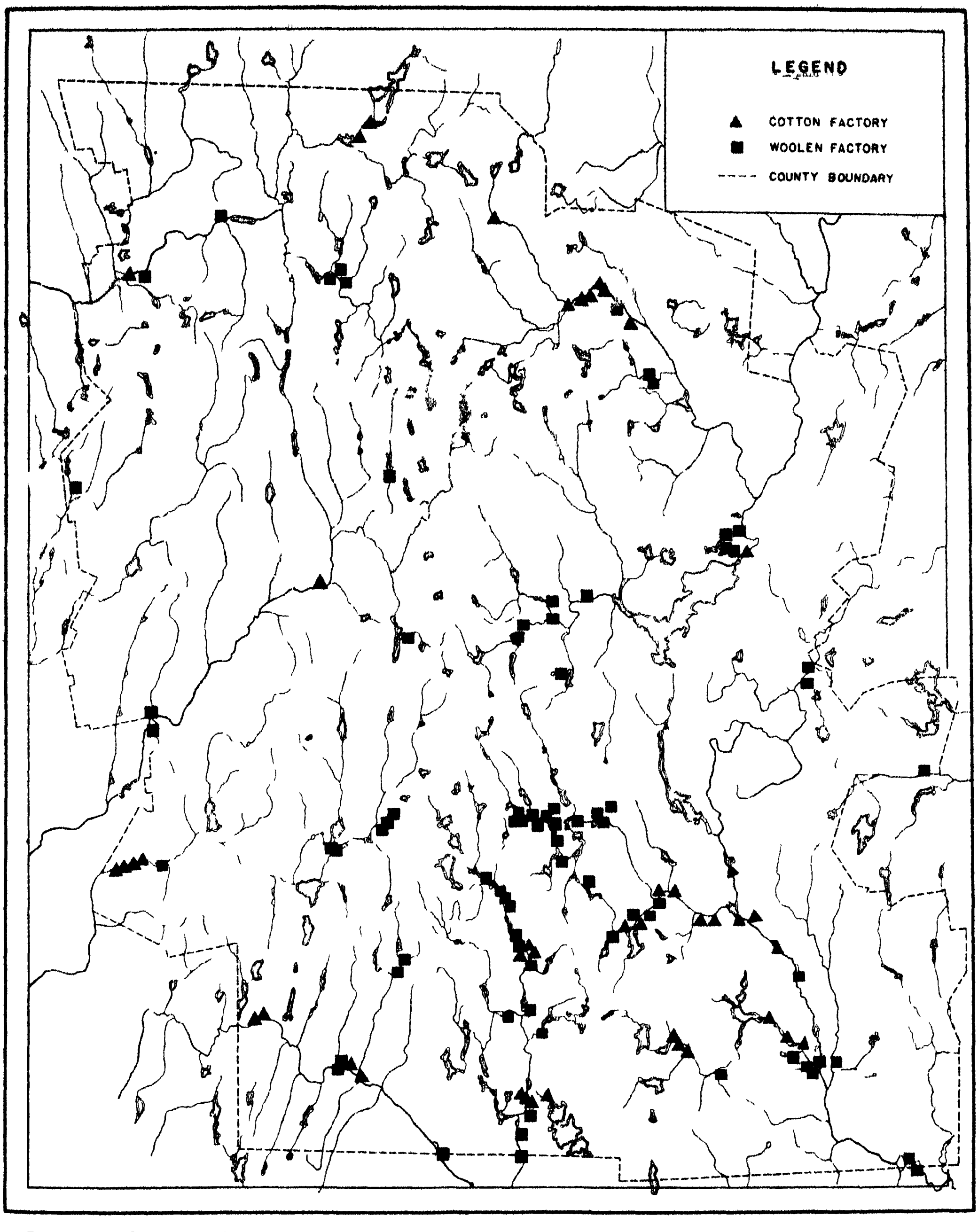
Several factors accounted for the rapid expansion of the agricultural frontier in the United States. Among the more important factors were the following: (1) Thousands of European peasants, poor in goods but ambitious to possess farms of their own, found the trip to the land of promise made possible by the improved means of transportation. (2) Industrial expansion in Europe provided growing markets for American grain. (3) The lure of the frontier and rumors of readily attainable wealth induced many easterners to go west (see Illus. below).

These factors were made particularly effective by the existence of extensive grasslands west of Indiana and the building of railroads in the middle part of the United States. The prairie soils were fertile and easily made productive; to place them under cultivation involved merely plowing up the sod—no slow clearing of forest was necessary and most of the land was boulder-free. Although on the new lands large yields were obtainable with relatively little effort, without markets these would have availed but little. The rivers, canals, and railways furnished outlets which provided the essential connections with the populous East and the seaports for shipments abroad (see Illus. below). The expansion of the agricultural era which characterized the period from 1840 to 1860 could not have occurred had the steam engine not been adapted to efficient transportation and had the land not been such that it could be quickly put into production.



Railroads in operation in 1860 The railways had barely begun to be consolidated into systems in 1840, but in the two decades following, the lines east of the Mississippi were operated largely as systems What were the most western cities served by railways in 1860? The pattern for the whole nation was not fully developed until about 1885 Adapted from C O Paullin and J K Wright. *Atlas of the Historical Geography of the United States* American Geographic Society, New York

This agricultural expansion had tremendous effects upon the economic life of the United States. The farmers on the rugged eastern lands found it increasingly difficult to compete in grain production with the fertile prairies of the Mississippi Valley. The developing west provided great markets for iron and steel to be used for building railroads and for the manufacture of farm machinery and household necessities. The increasing population gave rise to steadily expanding markets for manufac-



Location of principal cotton and woolen mills in Worcester County, Central Massachusetts, 1900 Consolidation of operation into larger power units, water power and steam plants, is evident Note contrast in pattern as compared with that in Illustration on page 337 tured goods, obtainable through sale of agricultural products. As New England found agriculture becoming increasingly unprofitable, her people turned more and more to industrial pursuits. The inhabitants of Pennsylvania became aware of the demands for coal, iron, and steel, and so they turned in greater numbers to coal mining and manufacturing (see Illus. p. 348).

Throughout this period the expansion of steam railways was the most striking movement. It stamped the life of the nation, and it gave emphasis to an industrialized northeast, a cotton-growing southeast, and a vast grain and cattle farming area in the Ohio and Upper Mississippi valleys. In this country it was the first act in the opening drama of steam, played while the curtain had not yet been lifted to reveal the potentialities of the trans-Missouri country.

The importance of capital. The Industrial Revolution, which made its first great impact in the New World before 1860 and continued for two or three decades beyond that date, would have been impossible at the outset if capital had not then been available with which to finance the rapidly expanding railroads and factories. Fortunately, the early nest egg of capital, earned through the profits of ocean shipping, gave liberal returns when set to work in industry during the early part of the nineteenth century. This success went far to establish credit abroad, and European investors became willing to furnish money at moderate returns on reasonable securities. Furthermore, the output of gold in California after 1848 furnished much needed capital during the latter part of this period. Money became plentiful and interest rates were relatively low. With capital at hand, with raw material abundant, and with markets expanding, the manufacturing industries were rapidly growing into the full stature of maturity when they were interrupted by the Civil War. Great things were ahead, although the day of their realization was postponed by the conflict.

Geographical significance of inventions. Nevertheless, all the lure of free land, the rewards of industrial toil, and the wonders of steam railways would have proved unavailable had not man done his part in providing labor-saving machinery. When labor is scarce it becomes costly, and man then becomes interested in utilizing it with the utmost efficiency. Thus arises the incentive for invention, and under this spur has come a large percentage of the improvements which have characterized the industrial era. American and European inventions together effectively promoted the industrial progress during the past century, and the New World with its rich rewards for inventive genius furnished the larger part of the economic incentive to progress along this line. By 1860 coal and steam were unchallenged in their supremacy in the realm of applied power, because they had vanquished their industrial predecessors and other competitors in the realm of power had not yet appeared. Coal and steam power had caused a far-reaching industrial revolution in the United States, while, during the same period, there occurred the greatest agricultural expansion that the world had ever experienced (refer again to pages 339-340).

The third period—the supremacy of steam and the advent of electricity, 1860-1910. The period of expansion prior to 1860 led the United States to the threshold of industrial greatness. The following half century was marked by the increasing importance of the nation and its gradual attainment of high rank within the inner circle of the world's great powers. Before 1860 the railroads had barely crossed the Mississippi River; in the following decades several lines, aided by government loans and land grants, were built to the Pacific Coast, and the Middle West was supplied with a railroad network that rivals in density that of the East. The agricultural frontier virtually disappeared when cattle raising, dry-farming methods, and irrigation changed the semiarid plains into productive lands, and domestic markets were extended to include all the territory of continental United States, an area of over three million square miles. The size of the country, with its diversity of climatic conditions, soils, and natural resources and the rapidly increasing population provided effective stimuli for development of production and trade. The absence of internal trade barriers encouraged each section of the country to engage in the activities for which it was best suited and to exchange its surplus products for needed goods from other sections. Among the changes wrought in the period 1860-1910, perhaps none was of more profound economic and social significance than the greatly increased industrialization. In 1860, the United States ranked so low in manufactures that it was of little consequence as an industrial nation; in 1910, it had become one of the leaders in manufacturing. The growth had been so gradual that few people sensed its import. Manufactures had expanded chiefly in response to the growing home demands, and the entry of American manufactured goods into world markets on a large scale had barely begun.

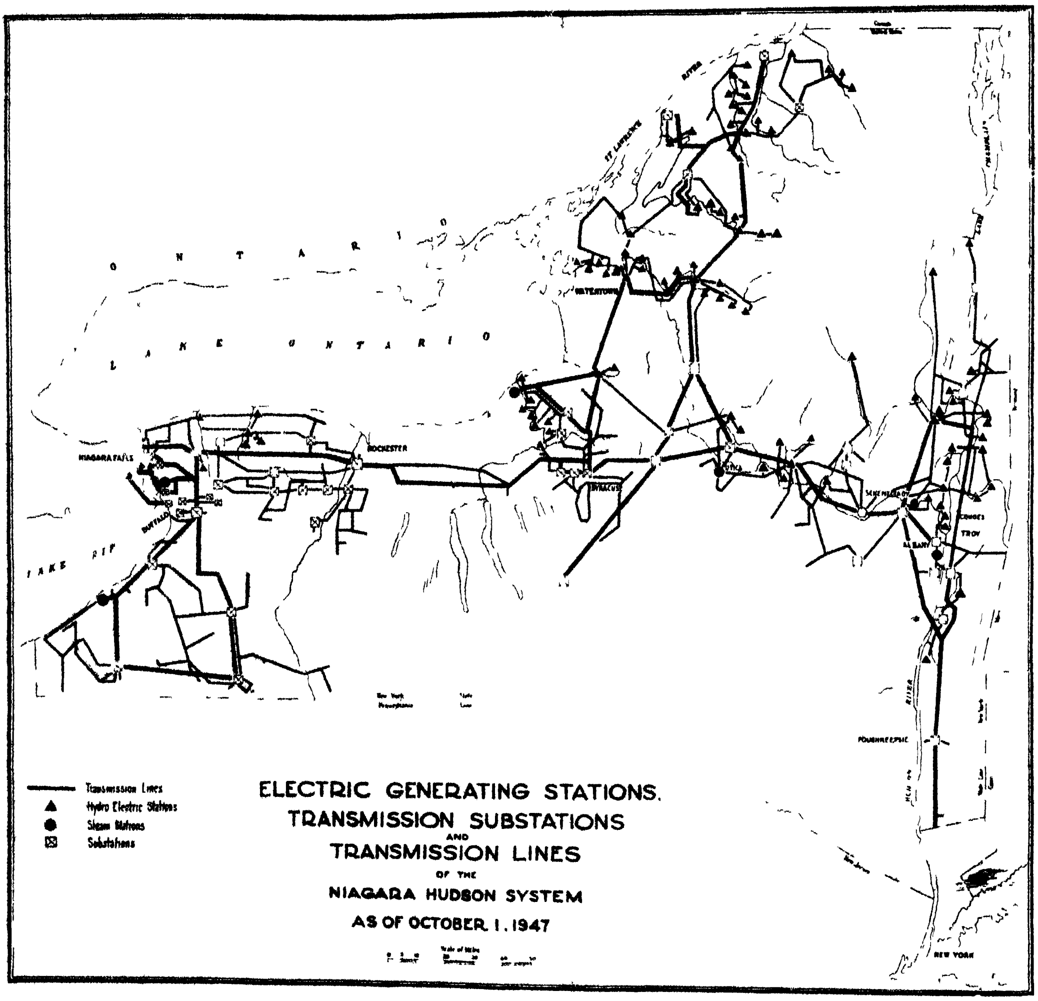
Tremendous as the growth of industrial power had been during the half century preceding 1910, it was not highly mobile power. Steam had to be used where generated. The boiler had to be operated near the engine, and, from the engine, power could be transmitted only by means of a leather belt to a near-by pulley shaft.

An event of major significance during this half-century period was the introduction of petroleum as a source of power. The expansion of production from the first well, drilled by Colonel Drake near Titusville, Pennsylvania, in 1859, to the far-flung oil fields of 1910 was a development of startling magnitude. From its first entry into commercial production in 1860, the output of petroleum in the United States increased to over 209 million barrels in 1910. Kerosene lamps displaced candles and tallow dips in nearly all countries of the world, a change so important that some students considered the kerosene lamp the most effective civilizing agent of the times. Petroleum also provided an inexpensive lubricant of superior quality when the machine age was calling for this product in large quantities. The development of high-speed machinery which marked the later years of the period was made possible by the high-quality lubricants derived from petroleum.

The most radical and far-reaching industrial event of the period was the introduction of electricity into the commercial field, starting with the incandescent electric light, Edison's epoch-making invention of October 21, 1879. By 1910 the use of electricity had spread far and wide, and, through its generation, water power had been developed on a scale little dreamed of in the days of the mill and brook. Electricity, although not yet at its zenith as industrial power, had become an important form of power applicable to industry. During the early part of the twentieth century, however, electricity was little more elastic than steam power, inasmuch as it could be delivered cheaply only to a compact and relatively congested population. Where population was sparse or communities remote, electricity was generally too costly for industrial use. As a consequence, both steam power and electricity were then conducive to concentration of industry near raw materials and particularly near centers where large markets were readily available. All these tendencies led to an increasing congestion of population and the concentration of industry and wealth in urban centers.

THE FOURTH PERIOD—THE AGE OF DISTRIBUTABLE POWER, 1910 TO THE PRESENT. Until about 1910 factory development tended to create small excessively compact industrial districts around nuclei of available power or great markets (see page 337). In the years immediately following, long-distance transmission of electricity became practicable, a change of such potential consequence that we look upon it as inaugurating a new stage in industrial progress. Since the resulting tendency is definitely toward decentralization of industrial enterprises, power available where needed tends to discourage undue congestion of population and thus serves to increase prosperity and well-being in general. Since 1910 there has been constructed in the United States an extensive network of high-voltage lines through which electrical power is distributed over a large part of the country (see Illus. below). An adequate supply of electricity for power and light is now indispensable not only to all of our cities but also to small towns and villages, and thus the electric public utilities today constitute a large sector of the business field with net investments that are estimated to exceed 14½ billion dollars.*

Other fundamental changes since 1910 include the construction of all-weather highways, the universal use of automobiles, improvements in railroad service, the adoption of airplanes as commercial carriers of



Electric generating stations in northern and northwestern New York state. Note that steam power plants for generating electricity occur throughout even this rich water power area. The map is intended to bring out emphatically the necessity of steam plants for generating electricity even where hydroelectric power is relatively abundant. The blank spaces on the map are served by other companies. The distribution system insures readiness of available power wherever and whenever needed—a remarkable achievement of the present age.

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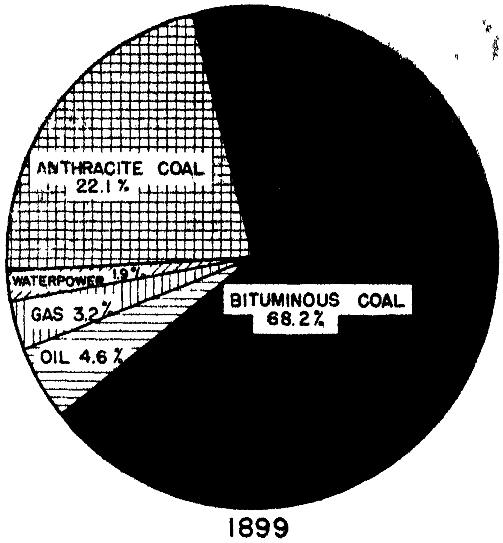
* Estimate by U. S. Federal Power Commission, April, 1949.

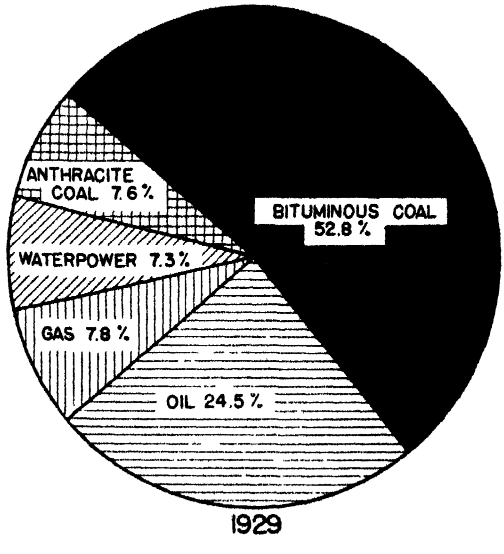
freight and passengers, and the inauguration of the first steps toward utilizing atomic energy. We can not yet measure the effects which will inevitably accompany these changes, but that their ultimate results will tend toward further decentralization of industrial plants appears to be inevitable. The automobile is largely responsible for the popularity of suburban residences, thus adding to the value of outlying lands while having the opposite effect on lands in the former peripheral areas of the cities. The decentralization tendencies in industry are already in evidence in the development of local manufacturing villages and towns associated with but located miles away from such great cities as Los Angeles, Detroit, Cleveland, and New York. The decrease in population density in the downtown sections of London, New York, and other large cities illustrates the effects of rapid transit on the distribution of city populations.

Although at present we know too little about the industrial possibilities of the use of atomic energy to forecast with any degree of certainty the effects which its control and utilization may involve, it seems highly probable that if and when it becomes available for industrial purposes, it will encourage further decentralization. Its use, which may become realized within the foreseeable future, seems certain to lessen to an even greater extent the need for concentration of people in the manufacture of goods. Even unharnessed, the atom encourages diffusion of industry as a defense measure so long as peace is not assured

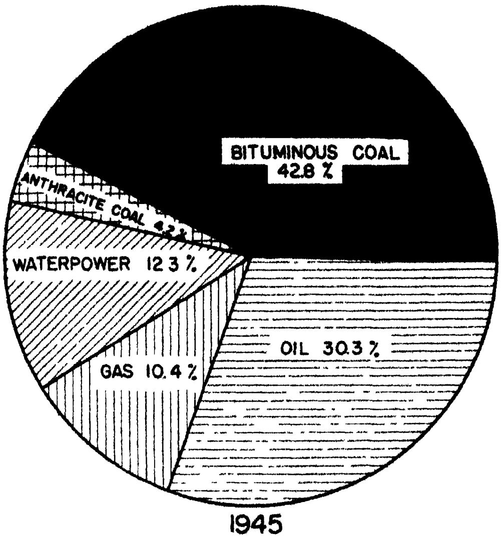


1899

Graphic illustrations of the relative shift in energy sources on a percentage basis since 1899 It should be noted however that the total energy now needed for power has increased so greatly that on a basis of tonnage *more* coal is needed than in 1899.



1929



1945

through international agreement. The movements now in progress toward developing smaller industrial centers where workers may have homes or individual plots of land are further illustrations of the decentralization made possible by distributable power. Although the movement toward decentralization is still in its earlier stages, and much further development must occur before its effects become generally apparent, we believe that continued progress along this line is assured.

Fundamental resources essential to industrial progress. When man succeeded in tapping large sources of natural energy, the way was open to eliminate much human drudgery. Man must of course continue to labor, but now his province lies essentially in directing machine activity instead of functioning personally as a primary source of power. The emancipation of man from the toil and inefficiency of earlier ages and his attainment of high per capita productivity are the fruits of our power-machine economy. Fundamental to this economy is the utilization of the great sources of energy: coal, petroleum, natural gas, water power, and, perhaps within the foreseeable future, atomic energy. The energy from these sources converted into power and applied to raw materials through machinery does the work of the times. It is to be expected that these trends will continue and that the zenith of material progress will be attained in due time, provided that the social and economic problems attendant with it are solved. It seems imperative, therefore, that if the values of harnessed power made available in its distributable forms are to serve mankind well, they must be made available to people everywhere. If such be possible, it may be truly said that, through energy available and applied as distributable power, there can be furnished food, clothing, shelter, and the comforts of travel and luxuries such as n people, not even the wealthiest classes, were privileged to enjoy in the past.

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Chapter Twenty-one

COAL—A PRIME FACTOR IN MODERN INDUSTRY

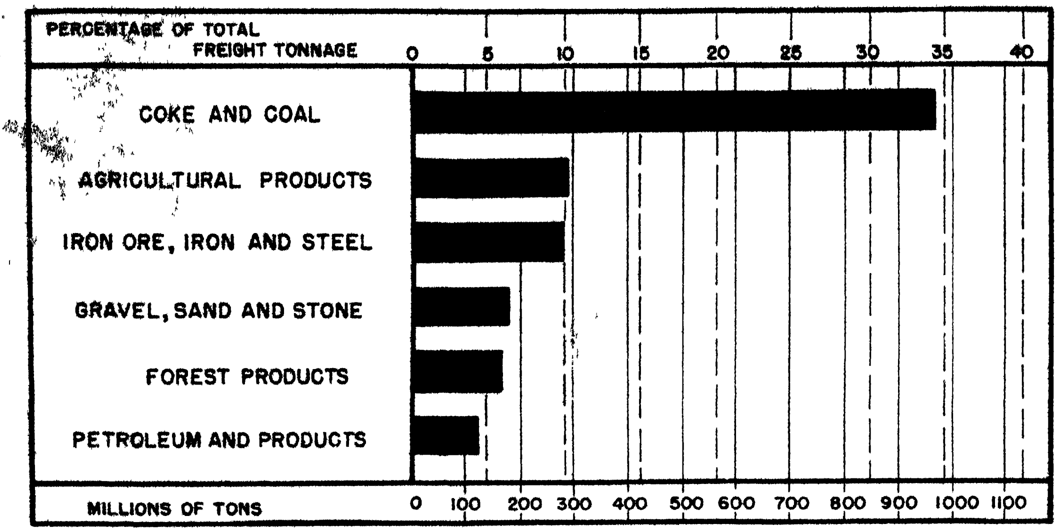
COAL WAS USED FOR HEATING SPACE long before it was discovered that its energy could be used to generate steam and thus be transformed into motive power for industrial purposes. The utilization of petroleum and natural gas followed; and when Portland cement became practical for building dams, large-scale water power added its contribution to the list of industrial forces. These developments have occurred in such rapid sequence during the past century that man is still bewildered by the social changes induced by them, changes that are still in progress.

The outlook for many years has tended to foster the belief that coal, petroleum, and natural gas, all of them nonreplenishable, would become depleted in the foreseeable future and that man's industrial progress would thus be halted, decline becoming inevitable. Fortunately, however, the natural stores of these irreplaceable power resources were great, discoveries have more than kept pace with the rapidly increasing demands, and thus the day of gloom continues to be deferred.

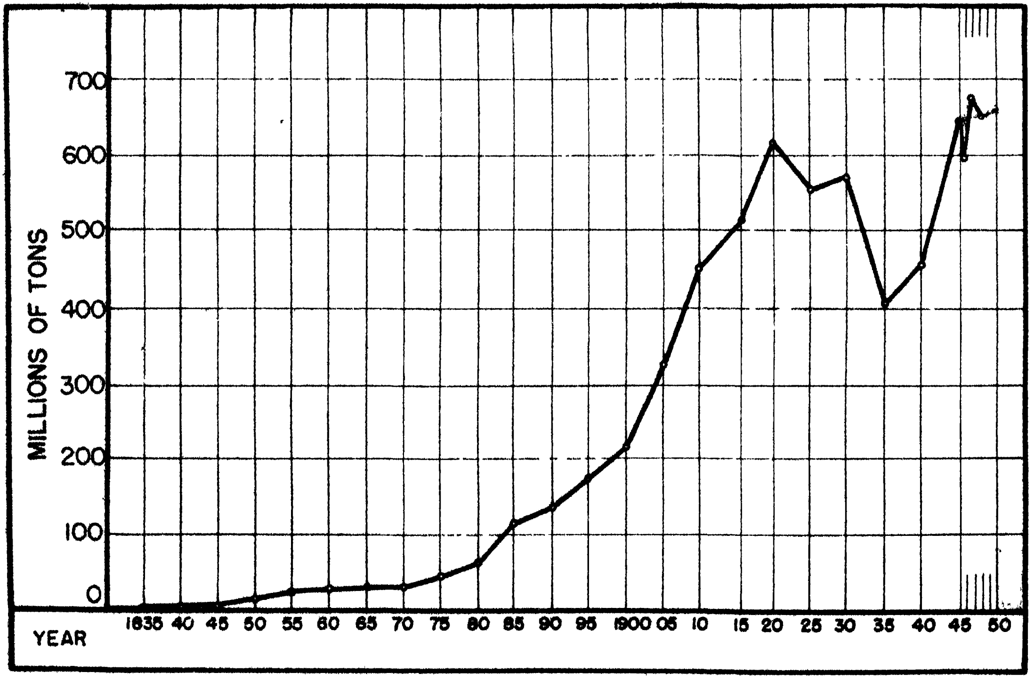
In recent years a new source of energy and potential power has been brought to light. Uranium is no longer merely a scientist's dream. Although not yet harnessed so as to be regarded as a ready source of industrial power, progress in that direction has been achieved to the point where success seems assured within a decade or two. If and when uranium becomes a source of energy and industrial power, it is probable that regions now rated as devoid of power resources may take on new significance. Such appears likely to become true of northern Canada, and of the Congo region of Africa, where stores of uranium ores are known to exist, and, of course, of other areas where uranium deposits may be discovered as the world-wide quest progresses.

Although changes may be impending through discoveries still to be made, coal remains the foremost fuel and power resource upon which modern industry depends. The enormous expansion of coal mining during the past century has been due largely to the introduction into our factories of labor-saving machinery and mechanical devices for power utilization; it is also true, however, that such machinery could not have been manufactured or utilized if coal had not been available to provide heat and dynamic power.

Generally speaking, the great industrial nations of the world are the great coal-using nations. The astounding material progress made by them has depended more upon coal than upon any other source of energy. Huge engines convert this energy into power for factory operations, steamship



(A.) Percentage freight tonnage of principal commodities carried by Class I, American steam railways, year ended December 31, 1947. Although details vary with different years, the general pattern holds steady. Source of data: *Freight Commodity Statistics*, Interstate Commerce Commission, Washington, D. C.



(B.) Coal production of the United States annually since 1830. How does one account for the sharp decline in output during the 1930's? Why the high production during 1945-1948?

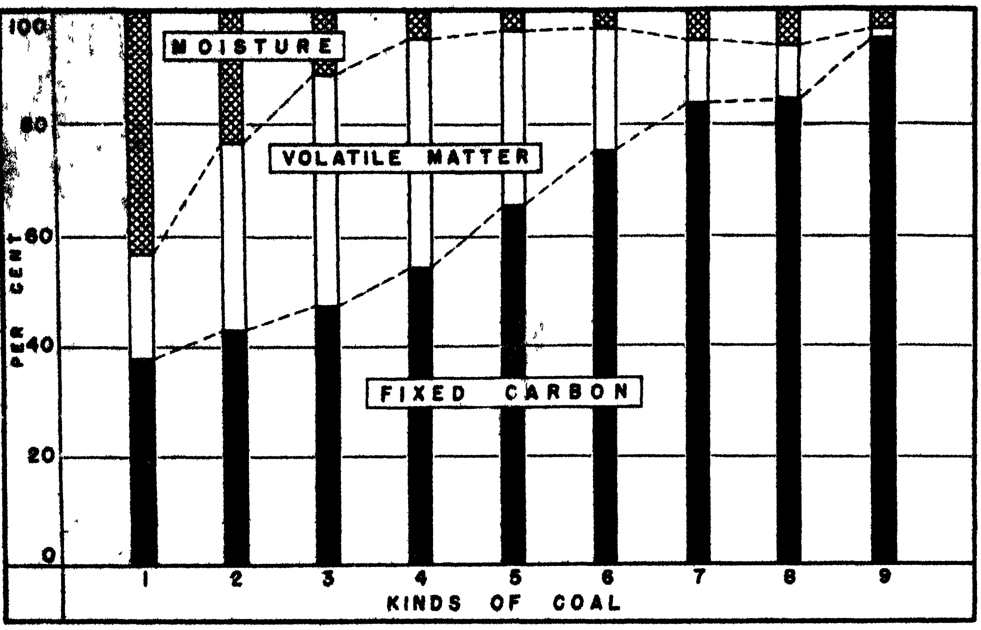
navigation, and railroad transportation. Coal is the principal fuel used in smelters, furnaces, and domestic heating plants. It is also the source of hundreds of products of organic chemistry, many of which are key materials without which a number of industrial processes would not be possible.

The economic significance of coal in the United States is evidenced by the fact that in a normal year the output of all kinds of coal is well over 600 million tons and also by the fact that coal mining gives direct employment to about 480,000 men. Coal has long been the greatest single item of railroad freight (see Illus. A, p. 348). The value of the annual output gives it rank among the leading three or four commodities produced in this country. The coal mining industry, because of its magnitude and intimate relations to other economic pursuits, has become recognized as one of the leading barometers of the nation's business. After the introduction of the steam engine, the demand for coal grew but slowly because wood was still available and the quantities needed were relatively small. Furthermore, the fireboxes for the boilers used in early steam plants were designed for wood and did not function well with coal. But as the steam engine was improved and enlarged in size, its fuel needs increased correspondingly. In response to this demand, fireboxes adapted for coal were designed and soon became successful. Because of the scarcity of timber in Europe, production of coal for power occurred there sooner than in America. But even so, it did not reach great importance in Europe until early in the nineteenth century, while in the United States coal really did not come into its own as a power fuel until after 1880 (see Illus. B, p. 348).

So far as is known, the earliest use of coal in what is now the United States was by the Hopi Indians of the southwest, who used coal for heating their homes at least three hundred years before the landing of the Pilgrims. During the colonial period some mining of coal was carried on by individuals who found outcrops along valley sides and took out small quantities for local use. Coal mining as an industry, however, can hardly be said to have existed in this country until after 1820. In 1821, the earliest year for which a record is available, the total output was only 1,322 tons. From then on, production increased gradually with annual tonnage relatively small, until the middle of the nineteenth century. From 1850 to 1920 each decade virtually doubled the output of the preceding one, a peak being reached during the period of World War I. Although marked fluctuations have characterized the years since 1920, the general level of coal output declined for a while because of the competition of petroleum and natural gas and the depression of the early 1930's. After the depression, there was gradual recovery until World War II again called for such heavy output of coal that the peak output of 1920 was surpassed. While the output induced by the demands of war may not soon be reached in peacetime, the trend appears to be stabilized at a high level. Increasing production seems likely to be resumed before another ten years shall have passed, this notwithstanding the sharp increase in efficiency of coal-burning industrial plants whereby in some instances a ton of coal is made to deliver two or three times as much power as it did in 1920.

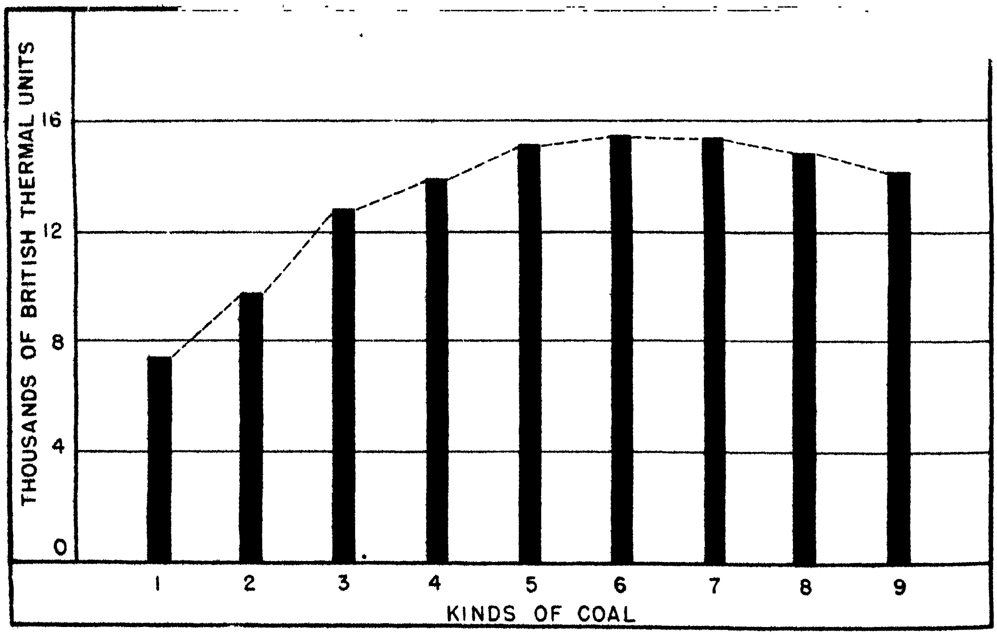
The important constituents of coal. The principal constituents of coal, those upon which its heat value depends, are fixed carbon, hydrocarbons, moisture, and ash. Coals with high percentages of fixed carbon and the hydrocarbons have relatively great heat value, while those with high moisture and ash content have low value (see Illus. A and B, p. 350).

Carbon is one of the principal products of the partial oxidation of woody matter. Since coal is of plant origin, carbon naturally is one of its major constituents. It is this element that imparts the black color and burns with little flame, high heat, and practically no smoke. Coals rich in carbon are usually low in the impurities which re-



(A.) Contents of different kinds of coal. (After M. R. Campbell, *Professional Paper 100*, United States Geological Survey, Washington, D. C.)

1. Lignite
2. Sub-bituminous
3. Bituminous, low rank
4. Bituminous, medium rank
5. Bituminous, high rank
6. Semi-bituminous, low rank
7. Semi-bituminous, high rank
8. Semi-anthracite
9. Anthracite

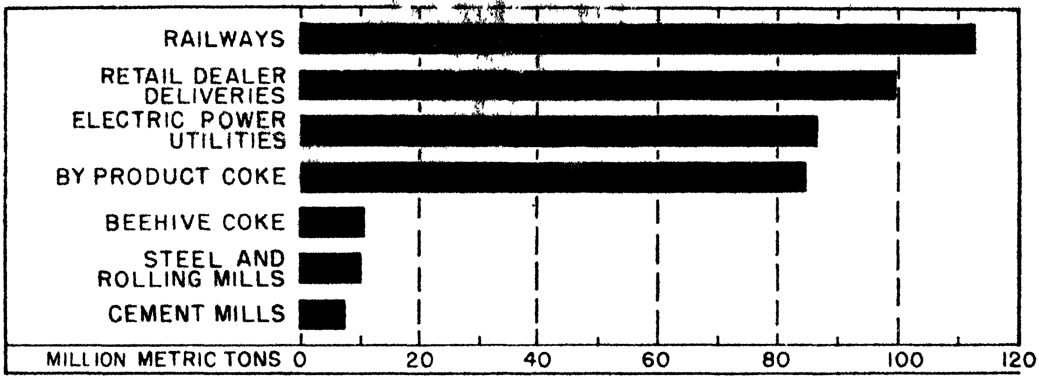


(B.) Heating value of different kinds of coal. How does the heat value of anthracite compare as to percentage with high-rank bituminous? How does high-rank bituminous compare with sub-bituminous? After M. R. Campbell. Sources as for previous illustration, same kinds of coal.

duce heat value, and the percentage of fixed carbon therefore is accepted in the trade as indicative of the quality of the coal.

The hydrocarbons consist of hydrogen and carbon, chemically united in varying proportions. These compounds, having from 1.3 to 4 times as much heat value as fixed carbon, increase the efficiency of coal as a fuel. Coals rich in hydrocarbons but low in moisture and ash are easily fired and are the most desirable for steam-generating purposes. Moisture in coal is, on the whole, an undesirable constituent. It has no heat value, and, by absorbing heat when coal burns, it reduces the efficiency of the fuel in somewhat greater ratio than is indicated by its percentage. Evaporation of contained moisture not only causes loss of weight in shipment or storage but if the moisture content exceeds 10 per cent it may cause chipping and crumbling whereby much of the coal is reduced to small particles, known to the trade as *slack,* thus seriously impairing the market value.

The ash content of coal is incombustible and therefore of no heat value. One per cent of ash is equivalent to 20 pounds per ton, and of course that represents waste in storage, handling, and transportation. Some coals have as high as 12 to 15 per cent ash, and in such cases the ash content becomes an important economic handicap. Steamship operators, for example, desire bunker coals with low ash content because of the business necessity to use all cargo space and tonnage to the best advantage. Ash is not economic cargo.



Consumption of bituminous coal by consumer classes, 1947. Note that railways are the greatest consumers of bituminous but are not far in advance of the electric power utilities as users of coal. How will the increase in the use of Diesel engines affect the demand for coal by railways? What labor problem may be involved in this trend?

Leading uses of coal. The uses of the coal mined in any given district are determined by a few principal factors: heating value, cleanliness, storage quality, coking or free-burning properties, and ability to compete with other coals or other fuels. In the United States the use of coal for power purposes, including transportation, ranks highest and accounts for about 36 per cent of the total output. All coals used for this purpose are known in the trade as *steam coals* (see Illus. above). About 19 per cent of the production is used in the manufacture of coke and by-products.

Kinds of coals. Classification of coal into a systematic series is credited to Parker and Campbell, who for a number of years were in charge of coal investigations for the United States Geological Survey. This classification has been widely accepted in the United States as scientifically sound and has proved practical for industrial purposes. Parker and Campbell began their series with peat and ended it with graphitic coal, although admittedly neither the first nor the last were coal in the sense that most people use the term. The successive members of the series from lignite to anthracite were ranked upon the basis of content of fixed carbon and hydrocarbons, and of coherence.

Peat. Peat occurs in bogs, especially in areas of cool-temperate climates where slow accumulation of partly altered vegetative fibers has given rise to deposits of varying extent and thickness. Its vegetative origin is clearly evident in the structure of the mass. The largest known deposits occur within the glaciated areas of the Northern Hemisphere, notably in Ireland, Scandinavia, Finland, the Soviet Union, north-central United States, and Canada. Peat is a bulky fuel which necessitates much storage space and involves high charges for shipment. When dried well it burns readily, gives a hot flame, and is comparatively low in ash content. Various attempts have been made to convert peat into smaller bulk through briquetting, but since this process adds materially to the cost, it is difficult for peat briquettes to compete with those made of fine coal.

Lignite. True lignite is brown or has a distinct brownish cast. The higher grades vary from dark brown to almost black. It is characterized by high moisture content, ranging from 20 to 35 per cent of the weight when freshly mined. The fixed carbon content ranges from 30 to 55 per cent, the lower percentage being more common than the higher. The structure is fibrous and, in some cases, woody. Among the principal handicaps to the use of lignite is its tendency to crumble to fine coal in shipment and in storage. While this fine coal has about as much heat value as the fresh lump, it burns less readily and therefore must often be marketed at a sacrifice.

In the United States there are extensive lignite deposits in North Dakota, northwest South Dakota, and eastern Montana. Lignite is also known to be present in large areas of the Gulf Coastal Plains from Texas to Alabama. However, little exploitation of lignite from any of these regions has yet occurred (see Illus. p. 356).

In Europe extensive beds of lignite are found in the north German lowlands, where they are mined on a large scale for the generation of electric power and various industrial purposes. One of the most important uses for lignite, one worked out by the Germans, is that of converting it into synthetic petroleum and petroleum products. Factories for converting coal and lignite into liquid and gaseous fuels apparently had reached a high degree of efficiency in Germany before World War II, because it is known that the Air Force of that country during the war depended to a considerable degree upon the liquid fuels thus obtained. The by-products of the manufacturing process have been found to be numerous and furnish essential materials for the chemical industries. It is evident that the ultimate possibilities of these processes have not been reached and that much progress along these lines may be expected in the future if natural petroleum becomes more expensive and perhaps inaccessible in some areas

Sub-bituminous coal. Sub-bituminous coal is often called *black lignite* in trade circles. Its color varies from dull to lustrous black, the structure is compact, and the fixed carbon ranges from 35 to 60 per cent. Most sub-bituminous coals are free-burning and clinker-free, and they have higher heat value than does lignite. The relatively high moisture content of this coal, often in excess of 12 per cent, constitutes a serious trade handicap, because evaporation causes crumbling and a resultant lower market value than for coals that can be handled with less deterioration. Upon being burned in locomotives or other furnaces with strong drafts, sub-bituminous coal often causes eruptions of sparks which become a fire menace to the vicinity. Nevertheless, coals of this class serve many important local market areas in the western plains where higher grade coals are remote and therefore expensive.

The best-known sub-bituminous coal region in the United States is found in the Great Plains in the so-called Sheridan District of northern Wyoming and the adjacent part of Montana (see Illus. p. 356). Coals of this kind occur also in the Denver Basin and in a number of basins within the Rocky Mountain Region. Because of the losses in weight and marketability which occur if the coal is kept long in storage, mining is largely seasonal. During autumn and winter, heavy demands lead to great activity; spring and summer are slack seasons when operations are almost at a standstill, except in the mines which serve railroads and local industrial plants.

It is unlikely that the near future will show any marked increase in the use of sub-bituminous coal in this country. In the more distant future, when petroleum will not be so plentiful as it is now, the utilization of this coal seems destined to increase because its hydrocarbon content makes it suitable for the manufacture of artificial gas and liquid fuels. The enormous quantities of sub-bituminous coal known to exist in the Great Plains and the Rocky Mountains, the comparatively low cost of mining in many places if all-year operation can be maintained, and the low cost of transporting liquid fuels are factors which some day may lead to extensive exploitation for liquefaction purposes. Another possibility which should not be discounted is that the coal may be converted to gas at the mine and thus be made available for transportation by pipeline from mines to industrial consumers. These changes are in prospect, experimental plants are in operation, but their day of realization on a commercial basis at present seems distant.

Bituminous coal. Bituminous coals are usually black, varying from dead black to highly lustrous. The moisture content is relatively low and in general the fixed carbon content ranges from 60 to 80 per cent and the volatile matter from 15 to 40 per cent. When some types are heated in closed retorts, the volatile matter goes off as gases and vapors, and the tarry materials may be drained off as liquids. These are captured for subsequent refinings and chemical processes by which over 200,000 products are made, varying from semiraw materials to finished products such as drugs, dyes, and perfumes.

Since bituminous coals break down more slowly upon exposure than do lower-grade coals, they may be kept in storage much longer. Bituminous coal constitutes about one-half of the estimated total world supply. In the United States the principal producing districts are in the Appalachian Plateau, extending from western Pennsylvania and eastern Ohio to Alabama, and in the interior plains of Michigan, Indiana, and Illinois and southwestward to Missouri, Kansas, and Oklahoma. Because of the rapidly expanding industrialism in the West, large and increasing tonnages of coal are being mined in Wyoming, Colorado, New Mexico, and Utah (see Illus. p. 356). Coals of this type furnish by far the larger part of the fuels used by the factories and railroads of the United States.

A special kind of bituminous coal characterized by its denseness and its dull black color is known as *cannel coal.* It burns with a long yellow flame and is especially well adapted for gasmaking and for quick kindling purposes in furnace operation. In late years it has become so expensive because of high costs of mining that its uses are chiefly as a fireplace fuel and for some kitchen ranges. The best-known cannel districts are in Kentucky and Tennessee.

Bituminous coals are broadly classified as *coking* or *noncoking.* Coking coals are those which can be fused when burned with an amount of air insufficient for complete combustion or when heated in retorts. More than 95 per cent of the coke is now made in byproduct retorts, also known as "slot type ovens," whereas in 1918 only about 50 per cent was so made. Earlier in the present century most of the coke was made in bee-hive ovens, which led to waste of gases now deemed highly valuable. The retort method of making coke permits the saving of all the by-products, the most important of which are gases and chemicals. Coke is essential in the smelting of iron ore because by its combustion it not only serves to provide the needed heat but also acts as a reducing agent for the oxide ores. By taking oxygen from the ore and adding carbon it leaves the molten metallic iron to settle to the base of the furnace as pig iron. A large percentage of the industrial coke is now made in by-product retorts located in connection with the iron and steel plants and where coal of coking quality is obtainable without long haulage. Pennsylvania is by far the leading state in coke manufacture; it is followed by Ohio, Indiana, New York, and Alabama. Extensive beds of coking coal occur in western Pennsylvania, Ohio, Kentucky, and West Virginia; these have contributed greatly to the development of the large industrial areas around Pittsburgh, Youngstown, and Cleveland.

SEMIBITUMINOUS COAL. Although the term *semibituminous* seems to imply that this grade of coal has half the rank of bituminous, it actually applies to a coal that is of higher and not lower rank. The color is rich black, usually of high luster. The fixed carbon content is high, 73 to 80 per cent; as a result, the coal burns with little smoke, and hence most semibituminous coals are known to the trade as *smokeless coal*. More technically it is referred to as low volatility coal. Because the moisture content is low and the heat value high, this coal is highly suitable for the generation of steam and for use in plants where high temperature operations prevail. It is used extensively in by-product retorts blended with high volatile coal to balance the oven operation. Its low percentage of ash and its nearly smokeless combustion cause it to be in great demand for bunker coal, especially for use in Scotch marine type of boilers.

The principal handicap of semibituminous coal is its friability, which causes it to crumble in mining and in transportation. Through the perfection of mechanical stokers and grates adapted to fine coal, this handicap has been overcome and for some purposes fineness is now an asset rather than a liability.

Semibituminous coals are found mostly in areas where the rocks have been moderately folded, because there the coal has been subjected to greater pressure than where the layers are nearly flat-lying. In the United States this condition prevails in the eastern parts of the Appalachian Plateau of Pennsylvania, Maryland, and West Virginia.

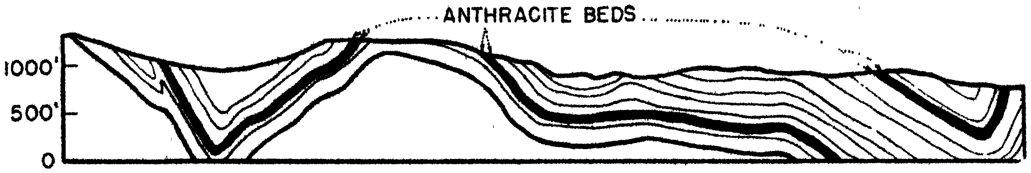
SEMIANTHRACITE COAL. Semianthracite coal differs from semibituminous in having a higher ratio of fixed carbon, 83 to 93 per cent, and a lower percentage of volatile matter. It differs from true anthracite in being more friable, which causes greater likelihood of its breaking down into fine coal as a result of handling.

The best-known mining districts are near Bernice, Pennsylvania, and along the flanks of the Ouachita Mountains in Arkansas and Oklahoma. Semianthracite coal is a clean-burning fuel and the heat value is as high as that of anthracite. Because it is almost smokeless, is free from soot, and burns slowly and persistently, it is desirable for fuel in domestic heating. It is therefore a popular furnace fuel throughout the large plains area tributary to the Ozark highlands, its main markets being the cities north and northwest of St. Louis.

ANTHRACITE. Anthracite is a hard and dense coal which is relatively free of iron compounds and moisture. The amount of fixed carbon is about the same as in semianthracite, ranging from 80 to as high as 95 per cent. It is jet black, lustrous, and of excellent coherence. The texture is fine, giving to the broken surface a smoothness which is almost a polish. It differs from semianthracite particularly in its hardness, a quality much desired because it permits preparation of sizes adapted to particular needs. Since there is virtually no loss in storage and no danger of spontaneous combustion, it is well adapted for summer purchase by consumers. This is an important factor in facilitating steady, monthly output of anthracite in contrast with the sharp fluctuations of some bituminous mines.

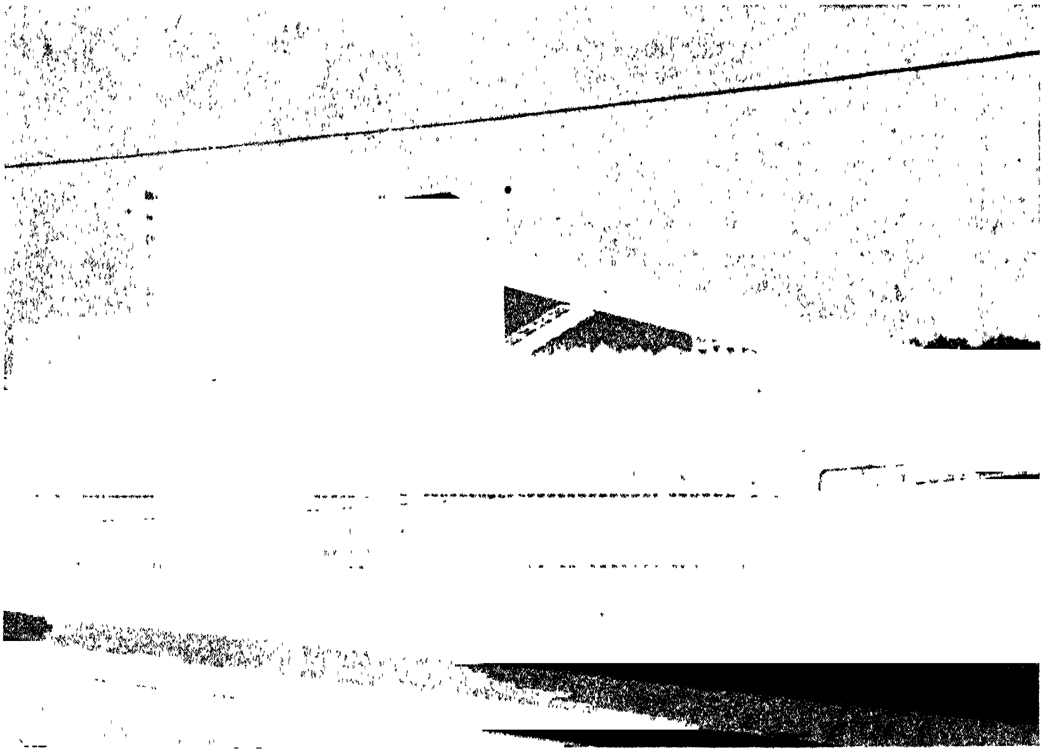
Anthracite burns with a short blue flame and gives practically no smoke. The fire is remarkably persistent and can be regulated to give much or little heat as conditions may require. All of these properties make anthracite the most popular of the coal series for heating homes and business blocks.

The structural conditions under which



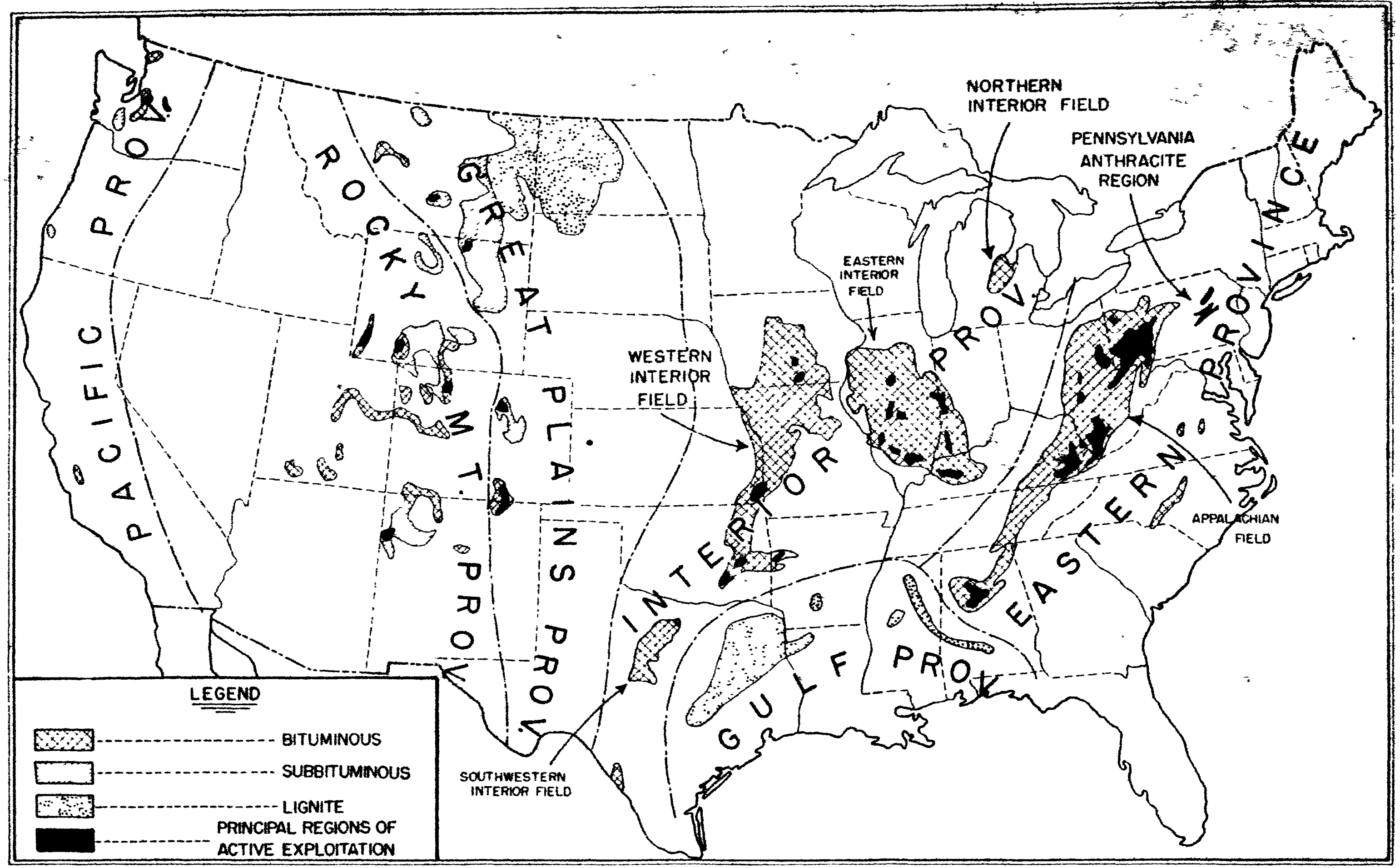
(A.) Diagram to illustrate the flexed structure characteristic of the anthracite fields, a condition that causes mining difficulties and necessarily greater expenses of production per ton of coal.

anthracite is found differ sharply from those that are prevalent in many bituminous areas (see Illus. above). In anthracite regions the beds are usually folded rather sharply and broken in places, a condition quite different from the flat-lying or gently inclined continuous beds characteristic of American bituminous regions. The folding is the result of tremendous lateral pressures which also are responsible for the metamorphosis, the change in structure, that is characteristic of anthracite. While this change has produced a fuel of high quality and desirability, the folding has caused difficult mining conditions. The steep slopes in the mines and, in some places, the disturbed arrangement of the strata, together with the prevalence of thinner beds, all add up to lower output per man and necessarily higher cost of production per ton. For example, in the United States in 1948 the average coal production per man-day was 6.7 tons in the bituminous industry and only 2.80 tons in the anthracite industry. These are the



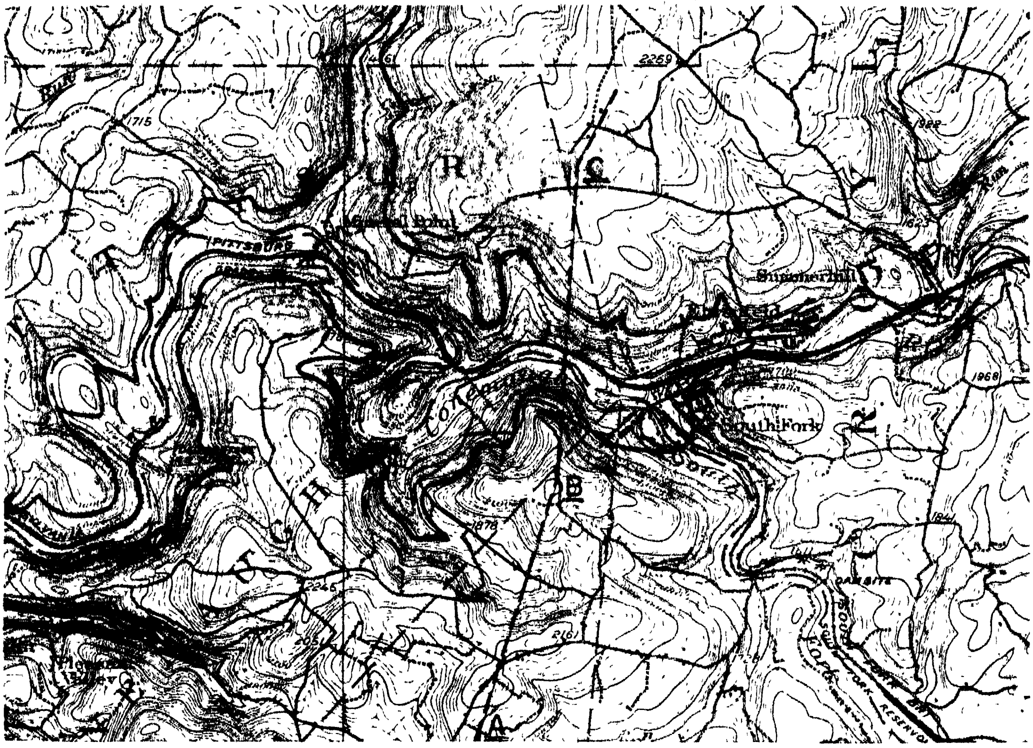
Courtesy Anthracite Institute, Wilkes-Barre, Pennsylvania.

(B.) One of the modern breakers in the anthracite region of northeast Pennsylvania. In such plants anthracite is sized, washed, and separated from impurities to meet consumer needs.



Coal provinces and major fields of coal mining in the United States.

factors that account for the high prices of anthracite in comparison with bituminous coals.



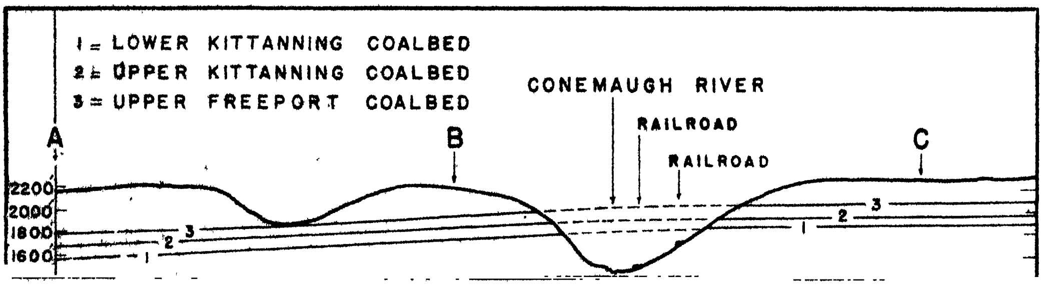
Topographic map of part of the bituminous coal field of the Appalachian Plateau, Cambria County, Pennsylvania. Outcrops of the principal coal bed shown by heavy black line. Mines indicated by crosses. For cross section of structure along line A-B-C see next page.

For steam purposes, anthracite is generally unable to compete with bituminous, but for space heating, its economic disadvantage is overcome by its persistent, clean-burning, and easily regulated heat. Furthermore, anthracite has the advantage of burning with practically no smoke, a quality to which must be attributed the comparatively clean atmosphere over the cities along our eastern seaboard. This advantage, however, is being overcome by the rapid introduction of smoke-consuming heat equipment for bituminous coal which is now being widely installed. Nevertheless, notwithstanding its comparatively high price, and because of the simplicity of use and the satisfactory service that it renders under diverse conditions, we may expect anthracite to continue to be in great demand.

In the United States there is only one prominent anthracite district, the so-called Scranton and Wilkes-Barre area of northeast Pennsylvania. It is a most fortunate circumstance that these large stores of high-grade anthracite are located so near to the most heavily populated section of the United States. The importance of the great markets close at hand may be readily appreciated when we are informed that in 1947 the average haul of prepared anthracite was only 164 miles compared to 305 miles for all sizes of bituminous coal. In the light of the total haulage involved, which was 8,051,200,996 ton-miles in that year, the availability of anthracite from this area for use in the densely populated northeastern states for heating homes, office buildings, and factories is and has long been of tremendous economic importance.

The distribution of coal in the United States. The coal fields of the United States are usually grouped under six major provinces: Eastern, Interior, Gulf Coast, Northern Great Plains, Rocky Mountain, and Pacific Coast. The names of these provinces are terms applied as a matter of convenience for the groupings of a number of fields within the respective general areas (see Illus. p. 356).

THE EASTERN PROVINCE. In output this province has always held commanding leadership. It leads the nation in production of both anthracite and bituminous coal, and it contains four of the five states which lead in coal output: Pennsylvania, West Virginia, Kentucky, and Ohio.


1 = LOWER KITTANNING COALBED
2 = UPPER KITTANNING COALBED
3 = UPPER FREEPORT COALBED
CONEMAUGH RIVER
RAILROAD
RAILROAD
A
B
C
2200
2000
1800
1600
1
2
3

Generalized profile along lines A-B-C of previous illustration to show the gentle slope of the coal beds in the area. Contrast with structure shown for anthracite in Illustration on page 355.

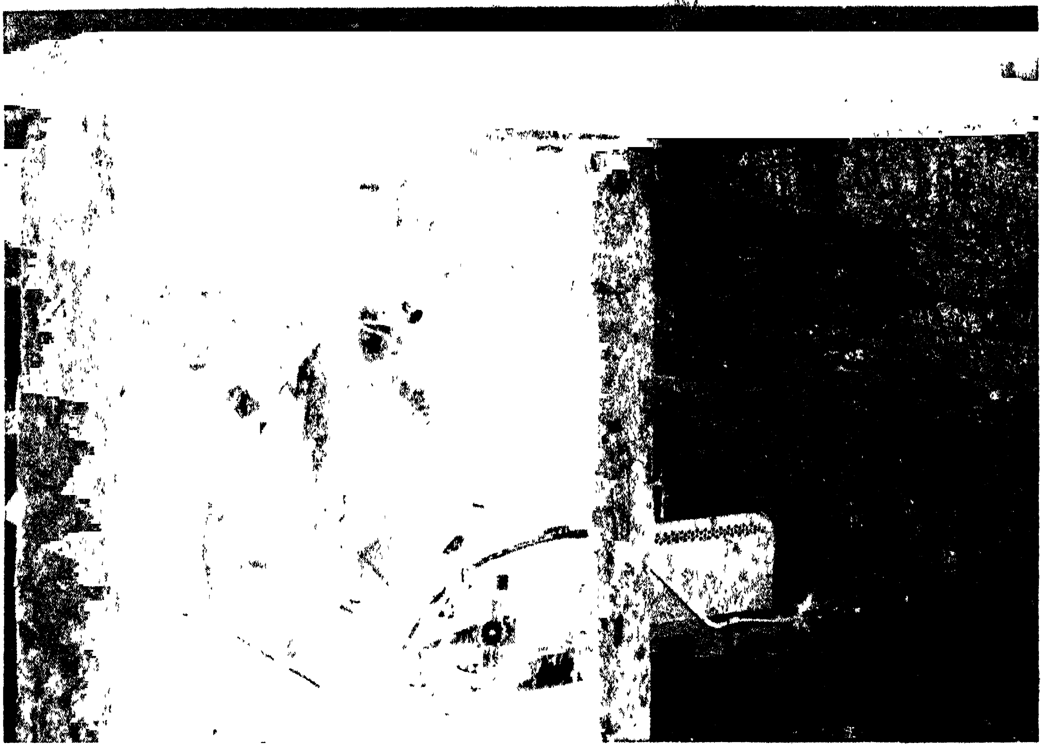
While anthracite accounts for only about one-eighth of the total annual output of the United States, its use for heating purposes in the densely populated northeastern sections of the country gives the anthracite region a much more important place in our economic scheme than its share in the total coal production might indicate.

The Eastern Province owes its economic supremacy, however, to the extent of the Appalachian bituminous field and the high quality of the accessible coal deposits there. From an industrial point of view, this field has been aptly termed the greatest in the world. It extends from northwestern Pennsylvania southward throughout the Appalachian Plateau into northern Alabama. The coal has high heat value and keeps well in storage. In addition, much of it is of unexcelled coking quality. The mining districts of this region furnish the industrial fuel for railroads and factories throughout eastern United States, and the coal has great importance also in gasmaking, in the generation of electric power, and in domestic heating.

On the whole, the structural conditions within the Appalachian bituminous field are favorable for low-cost mining. The beds, often referred to as *seams*, are flat-lying or gently inclined and continuous over relatively large areas, without great change in thickness or quality. The coal seams are interbedded with limestones and hard shales, which provide good floors and comparatively safe roofs for underground mining operations. Major and many minor streams of the area have cut narrow valleys to such depth that one or more of the coal beds have been exposed along the valley sides. This facilitates the development of mining by means of drifts and tunnels above the level of ground water and provides comparatively simple problems of drainage of the mines and transportation of the coals out of the mines into the railways built along the valleys (see Illus. p. 357 and above). These conditions, coupled with large available market demands, favor the huge investments which are necessary for safe and efficient production. As a result, the mines in operation in the Appalachian field are now largely mechanized.

which makes possible an increased output per man per hour, with increased safety and higher income per capita. The significance of these mining conditions and the mechanization now operative is clearly demonstrated by the fact that in 1947 the average coal production per man-day in all bituminous mines of the United States was 6.42 tons, whereas in Canada, in the same year, only 2.80 tons were produced per man-day, and in Great Britain only 1.20 tons. In many of the European fields the natural conditions are such that the output per man per day, even with all the mechanization that can be used advantageously, cannot equal that of the American fields (see Illus. above and on next page).

A remarkable development within the coal-mining industry during the past decade has been the growth of *strip mining.* In this method the overburden of rock, clay, and shale, is removed by huge tractor-propelled machines called "overburden shovels," whereupon the coal is then mined by open-cut methods, thus making unnecessary the expensive tunnels, shafts, and timbering that must be used for underground mining. The strip-mining method is carried on in many states, and the Appalachian field is one of the foremost in this new development. The combined output of Pennsylvania and West Virginia by strip mining in 1947 was 51,556,000 tons, compared with an annual average of only 1,436,000 tons during the 1935-1939 period. There will of course be a limit to the extent to which strip mining may be carried on, because only such beds as are located at relatively shallow depths can profitably be mined by this method.



Courtesy U. S. Bureau of Mines

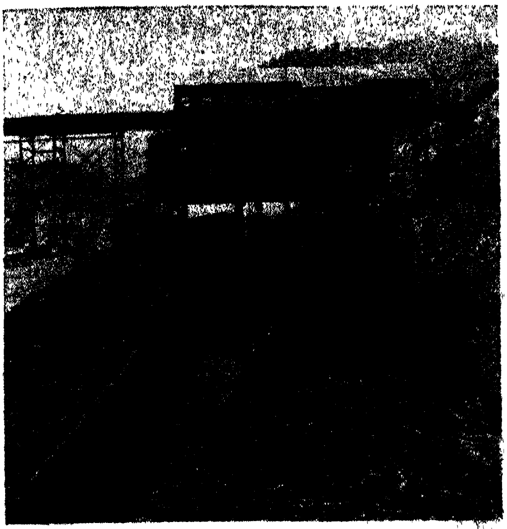
Undercutting a coal bed as an early step in coal mining. Water is sprayed to prevent accumulation of explosive dust.

The bituminous coals of the Eastern Province have for decades served highly important purposes throughout the section of the United States that has developed to the greatest extent industrially. The American smelting industry, particularly iron and steel, has been dependent to a large extent upon the high-grade coke obtainable from this region. Furthermore it has been possible for the railways, as well as the manufacturing industries, to be supplied with steam coals at minimum rates. Although this coal field has in recent years felt competition to a somewhat retarding degree from the petroleum and natural gas reserves that have been and are now being made available from distant sources, it seems that the demands for coal must continue to increase because of the increasing pressure upon industry made by a nation still expanding rapidly in population. Furthermore, although the reserves may be sufficient to supply eastern United States for some years with gas and petroleum from the Lower Mississippi Valley and Kansas and Texas the economy of this movement, from a long-time point of view, is questionable. The reserves of coal are so great that we may safely consider them to be available for centuries to come, whereas the reserves of natural gas and petroleum cannot now be stated in terms beyond that of some decades to come. Industrial United States must face the question of the ultimate wisdom of transporting fuels in liquid and gaseous form to eastern consumers from the limited stores of the Middle West while high-grade solid fuels in much greater abundance are close at hand. It is merely a repetition of the old question as to whether it is wise to live for a day or plan for the future.

Courtesy U S Bureau of Mines

Loading bituminous coal by machine in operation at face of workings. Loader at right foreground transfers coal to mine car at left. What effect does power driven machinery have on coal output per man per day?

The Interior Province. The Interior Province includes four areas referred to as fields. They have been mapped as (1) the Northern Interior field of Michigan, (2)

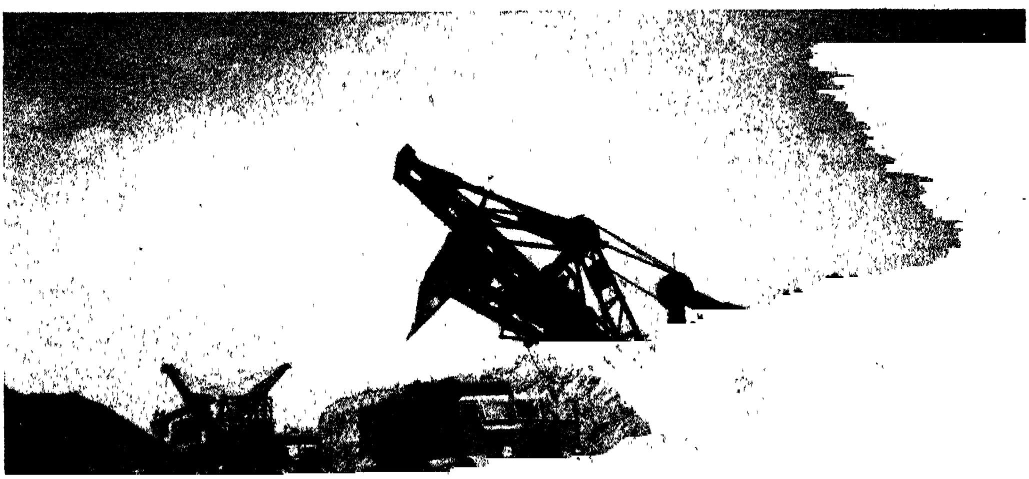


Courtesy Bituminous Coal Institute, Washington, D. C.

(A.) Bituminous coal of different sizes being loaded into railway cars from the sorting screens in the tipple. This is a common sight in eastern bituminous fields.

the Eastern Interior field of Indiana, Illinois, and Western Kentucky, (3) the Western Interior field, embracing the coal-producing areas of Iowa, Missouri, Kansas, Oklahoma, and Arkansas, and (4) the Southwestern Interior field of Texas. The first three have attained high commercial importance, but the last-named has been exploited but slightly to date (see Illus. p. 356).

The coals of the Northern and Eastern Interior fields owe their economic importance chiefly to the demands of industry and transportation. However, in addition to these demands, the comparative density of population and the severity of the weather during the winter months give rise to a large market for coal for heating homes, office buildings, and industrial plants. The coal of Michigan is an important asset for Detroit and for other industrial centers in the southern part of the state. The Indiana, Illinois, and western Kentucky coals find markets in the great industrial cities within and adjacent to those states. The coal throughout this area lies in beds of simple stratification and within easy reach by strip-mining methods or comparatively shallow underground mining. Illinois, which is particularly fortunate in the extensiveness of its coal resources, in the low cost of min-



Courtesy Bituminous Institute, Washington, D. C.

(B.) Strip mining, bituminous coal in southeastern Kansas. View reveals size of equipment used, shovel, dragline, loader, and 40-ton trucks in operation.

ing operations, in the high quality of coal, and in the availability of large markets—particularly those of the Chicago and St. Louis industrial areas—has become one of the three states leading in coal output.

A factor of great importance to the coal industry of the interior states east of the Mississippi is the Great Lakes waterway which provides a cheap transportation route to the markets of northern United States and adjacent parts of Canada, where the winters are long and severe and local coal supplies are wanting (see Illus. p. 423).✓ Because of the heavy southward movement of iron ore, competition for northbound cargo is so keen that the coals of the Appalachian field—Pennsylvania, West Virginia, Kentucky, and eastern Ohio—compete with the coals of the interior fields for the northern markets.

The coal of the Western Interior field is characterized by high heat value and by a range in quality from anthracite to bituminous. On the flanks of the Ouachita Mountains of Arkansas and Oklahoma, folding has caused metamorphism of the coal into the high fixed carbon group. Since it is friable rather than coherent and hard, most of it is classified as semianthracite, although its fixed carbon content is nearly as high as that of the well-known Pennsylvania anthracite. Elsewhere in the Western Interior field only the bituminous coals are found. However, they have exceptionally high heat value, some of them ranking with the hottest coals we have in the United States, and their low cost at the mines makes them a highly prized steam coal for industrial and railway uses (see Illus. p. 356). In southeast Kansas, particularly, extensive strip mining is in operation with resultant low cost of production, a factor which extends the trade territory of the coal for steam purposes (see Illus. B, p. 361).

Notwithstanding the high heating value of the bituminous coal of this area, its exploitation is somewhat handicapped by competition with petroleum and natural gas. These fuel resources are found in great abundance within the same general area as is the coal. Their exploitation has proved so successful and the reserves so great that there has been but little tendency to conserve them for later demands rather than to meet the coal on a competitive basis. Exploitation is limited also by the comparative sparseness of population and of industrial plants within the adjacent trade territory.

The Southwest Interior field is in central Texas. The coal is bituminous, is not of very high grade, and has but little economic value at present because of competition with petroleum and natural gas.

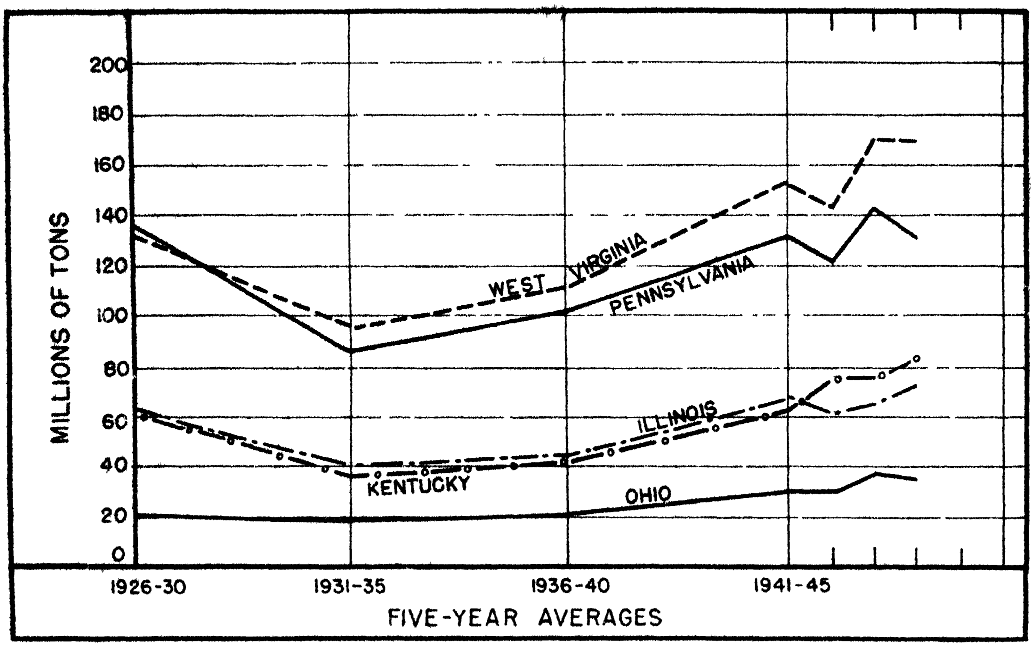
THE GULF COAST PROVINCE. The Gulf Coast Province extends from Texas to Alabama (see Illus. p. 356). Only lignite has been found there. The poor quality, difficult mining conditions, and competition with superior fuels have prevented any extensive exploitation to date. Inasmuch as there is no prospect of improvement in the near future, this area must be marked off as having no immediate significant value, but it serves as a reserve for the time that may come when it can be successfully exploited for the manufacture of gas or liquid fuels.

THE WESTERN PROVINCE. The Northern Great Plains and the Rocky Mountain districts contain enormous reserves of unmined coal, varying from lignite to high-quality bituminous, with a few places where coal of anthracite quality has been found. Exploitation has been chiefly for railway use, for smelters, and for domestic heating. Local mines have long been highly important to the communities which they serve and to the railroads which traverse the regions. The mining and smelting industries of the Rocky Mountain districts have been enabled to operate at relatively low cost because of the coal available from near-by sources. The total amount of coal produced has been small in comparison with the production of the eastern fields, because of the sparseness of the population in the vast territory included within these provinces and the distances to outside markets. The large iron and steel plants recently constructed and some others reputed to be planned presage increased demand for coal. Commercial exploitation is not likely to increase rapidly, however, so long as cheap petroleum and natural gas are available to the industrial centers. Nevertheless, the great reserves of coal known to exist within the Great Plains and the basins of the Rocky Mountain region afford us assurance that the country need have no fear of a fuel famine for centuries to come.

THE PACIFIC COAST PROVINCE. The Pacific Coast Province includes the coal fields of Washington and Oregon, with a few small areas in California. The fields are small. There is but little coking coal, so far as is known, and mining conditions are difficult. Exploitation must meet the competition of coal from Alaska and crude oil from California, which are available at low shipping rates. Domestic demands are light because of the mild winters characteristic of the Pacific Northwest. The railroads have greatly expanded their electrification programs, made possible by the development of the water-power resources of this part of the country, and have thereby reduced their demands for coal. On the other hand, the Pacific Coast states have witnessed during the past decade a tremendous development of heavy industry, with resultant increasing demands for power. Despite the marvelous development of hydroelectricity made available by the great projects along the Columbia, Sacramento, and Colorado rivers, the heavy exploitation of petroleum in the California fields, and, lately, the introduction of gas from the interior fields of Texas and Oklahoma, a shortage of power is imminent. Coal appears to be the logical source for the increasing quantities of power needed to satisfy the industrial demands. For that reason there has come into the picture in the northwest the prospect of continued development of the coal resources of the Pacific Province and perhaps even the likelihood of use of the Alaskan coal resources which can be obtained by means of water transport.

The geographical significance of the distribution of coal in the United States. The United States is unique for its large coal reserves in the interior, which are readily available for exploitation. Among the various economic effects of the distribution of the coal fields, three outstanding ones deserve emphasis. First, the coal fields of eastern United States are more than two hundred miles from tidewater ports. Railway transportation across rugged mountainous country from mine to seaport adds materially to the cost of the coal at the seaboard. This factor is a handicap to the development of a large export trade because of the competition of European coals mined near tidewater or navigable streams where the land transportation costs are slight. Second, the wide distribution of coal in the interior has furnished the power necessary for a wideflung and intricate network of railroads and for industrial and agricultural development there such as no other continent has ever experienced. The transcontinental railroad systems are provided with natural refueling stations because of available coal at relatively convenient intervals throughout their routes. Third, had there been coal along the coasts but not in the interior, the costs of hauling agricultural products to eastern industrial centers or to seaboard markets would have been much higher, in some cases prohibitive, and agricultural prosperity within the interior of the continent could not have been achieved. Without agricultural prosperity, industrial growth in the interior would have been impossible. Without the great markets of the Middle West and the Rockies, the industrial progress of the East would have been seriously curtailed. While, of course, other factors are involved also, the coal fields of the interior from Pennsylvania to Colorado and Utah deserve much of the credit for the energy and industrial progress of the United States.

Coal production in the United States. The annual production of all coal in the United States since 1940 has averaged over 600 million tons (see Illus. B, p. 348). Pennsylvania anthracite accounts for about 10 per cent of the total production. In the output of bituminous coal, West Virginia continues to hold commanding lead, with Pennsylvania second. Illinois and Kentucky usually rank third and fourth, although either may outrank the other in any given year, and Ohio has consistently held fifth place. The importance of coal to the development of centers of heavy industry such as Pittsburgh, Cleveland, Detroit, and Chicago is evident (see Illus. p. 427).



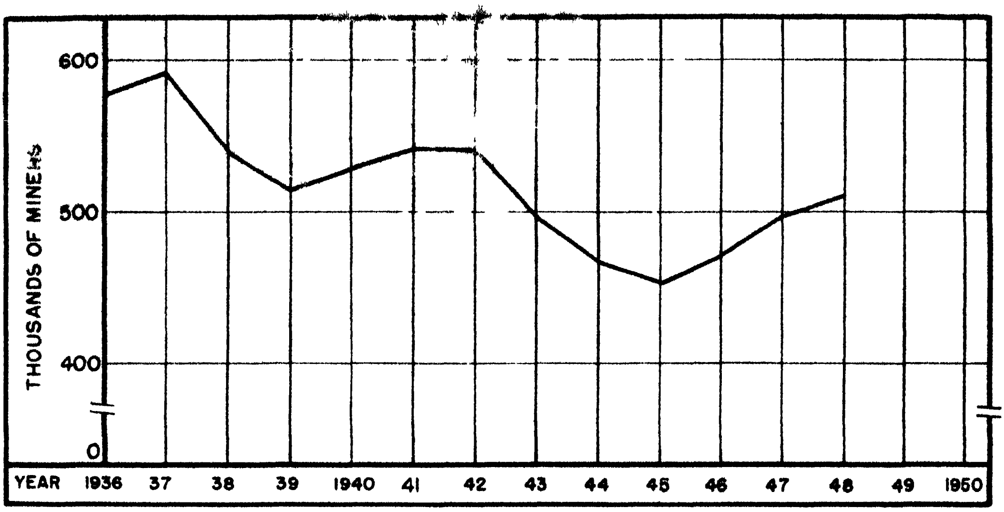
Annual production of bituminous coal in the five leading states, 5-year period averages from 1926 to 1940, since then yearly. Note the persistent leadership of West Virginia and the increasing prominence of Kentucky since 1940.

United States foreign trade in coal. Exports of American coal during the period preceding World War II constituted but a small fraction of the total output, usually between 2 and 6 per cent. Canada was then and continues now to be the foremost export market, taking nearly all of the anthracite exports and from 85 to 90 per cent of the bituminous exports. The importation of coal from the United States is favored by the geographical proximity of the American coal fields to the most densely populated part of Canada and by the remoteness of the Canadian reserves, which are located mostly in the western plains country, in the basins of the western mountains, and far to the east in the maritime provinces, particularly Nova Scotia.

The Caribbean lands buy some American coal, but their needs are not great. In the larger South American markets competitive conditions exist and the American exporters find it difficult to meet prices quoted by the Europeans—particularly the British. Because of the intimate trade relationships that exist between Brazil and the United States, that country is ordinarily a better market for American coal than is Argentina. The United States is the greatest customer for Brazil's foremost export, coffee. Argentina, on the other hand, exports grain and meats for which England is a market of exceptional importance. Outward-bound British ships naturally carry coal as part of their cargo, because Argentina's other imports are commodities of high value in proportion to weight, such as electrical goods, machinery, chemicals, and textiles, which demand less cargo space than is the case for the bulky exports of grain, wool, and hides from that country.

During the prewar period American exports to European markets were small because European coals are mined near the seaboard or where water routes are available from the interior. As coal is bulky in proportion to value, low-cost water transportation from mine to market is a decided advantage for trade.

The export trade in American coal was greatly expanded during the war period and the years immediately following, particularly with European countries. For example, during the prewar period, 1935-1939, our average exports of bituminous coal were only slightly more than 11 million tons, or 2.8 per cent of the total output. During the five-year war period, 1940-1944, our average exports of bituminous coal were more than double those of the prewar period. During the postwar period the increase continued so that in 1947 the tonnage had increased sixfold over the prewar period and made up 11 per cent of the expanded production of 620 million tons of bituminous coal in that year. The change in export trade of anthracite followed the same general pattern, exports increasing from 3.8 per cent of production during the prewar period to 6.4 per cent during the war period. In 1946 our exports of anthracite reached the astounding proportion of nearly 11 per cent of the total production of 60,507,000 tons.



Total number of miners employed in the anthracite and bituminous coal mining industries annually since 1936. Mechanization makes possible high daily output per man and lower cost per ton.

The causes for the great increase in exports were the complete disorganization of coal mining in important centers in western Europe due to the war and the retarded rate of mining, even in Great Britain. In 1947 and 1948 large quantities of American coal were exported to France and Italy and to each of the countries of northern Europe as well as to South American countries which ordinarily are well supplied from British and German sources. Europe took more than 53 per cent of our total exports in 1947, compared with less than one-half per cent during the 1935-1939 period. That this represents but a temporary condition must be recognized, because with the restoration of coal production in Germany and the countries of western Europe, it will be to their interests that the European demand be supplied from European sources.

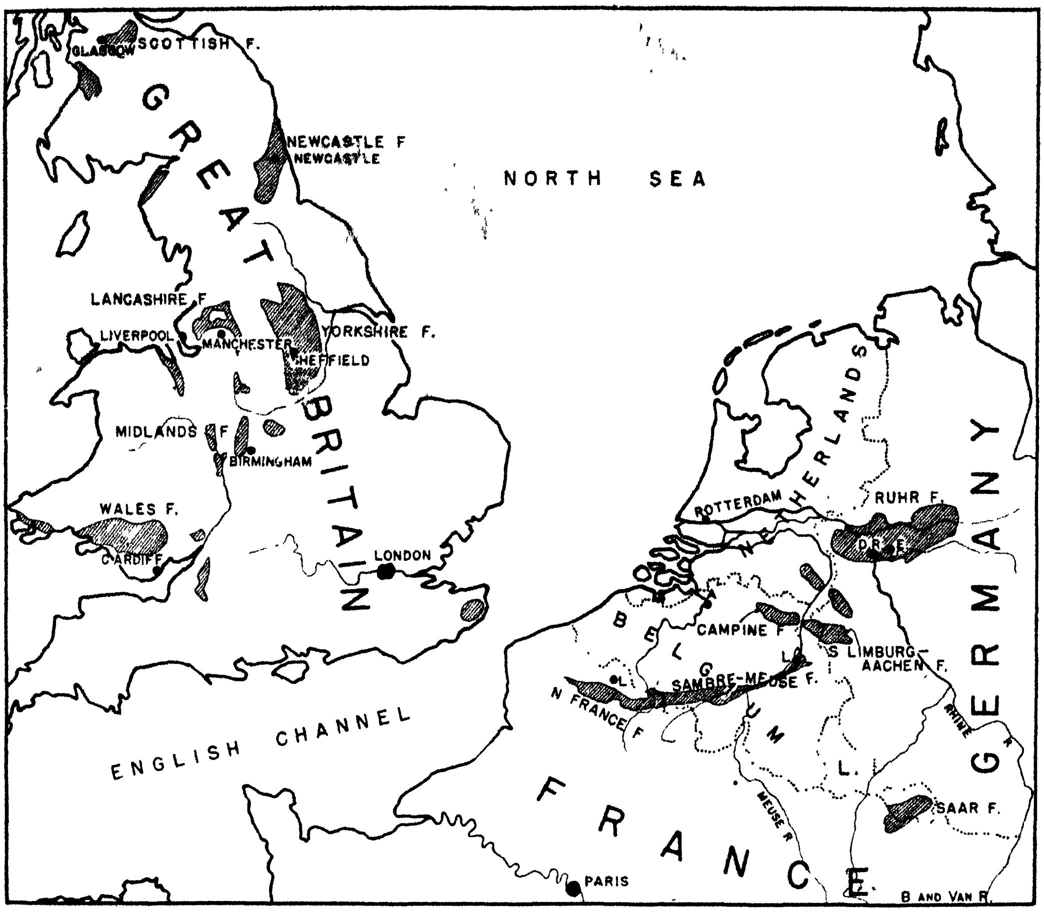
On a permanent basis, therefore, it is not to be expected that the export trade in American coal will increase very much above the prewar level. Some increase may be expected because of expanding markets due to increasing industrialization in the Western Hemisphere. In this connection, however, the increasing use of petroleum fuels for bunkering purposes and strong competition from foreign sources of coal are factors which point rather conclusively to limitations on the demands for American coal for export and for marine purposes.

Some problems of the American coal industry. The coal-mining industry of the United States is capable of much greater production and may be expected to meet successfully any enlarged demand for coal that may come within the foreseeable future. In the past the coal industry has had to contend with strong seasonal fluctuations in demand. To meet peak demands, overexpansion of labor supply was induced with resultant unemployment during the slack periods. Seasonal fluctuations in demand have been overcome in considerable measure through a widely dispersed system of storage of coal for domestic and industrial uses. It can hardly be expected that seasonal demands can be equalized, but they have changed from a curve of sharp peaks and drops to one of gentle undulations. Increased efficiency is being facilitated also by the extensive use of mechanized methods whereby the rate of production is speeded up and the efficiency of labor greatly increased. The changes that have occurred since the prewar period are pointing the way. During the 1935-1939 period, the average number of days worked in the American bituminous mines was only 182, whereas, in the period following, no year has shown less than 200, and in 1944 the mines were in operation 278 working days. The number of workers employed has shown rather steady decrease since 1935, and this in the face of increasing tonnage of coal produced. This increase in tonnage has been made possible by increased mechanization with attendant greater output per man per day and, incidentally, also higher wages per man.

The American coal industry, in common with all other great enterprises, faces many problems, and the hopeful aspect is that the industry itself is cognizant of them. Huge sums of money are being spent by the coal industry in both the anthracite and bituminous fields for the promotion of research so that waste may be eliminated, by-products be fully used, and the efficiency of methods of production and of use be greatly improved. The value of this type of work cannot be expressed in dollars and cents at any given time, because research must always be primarily a search for truth, not dollars. However, the net effects are shown in the improved conditions that are characteristic all along the line from the depths of the mine to the realms of fine consumer goods, including textiles, drugs, and perfumes.

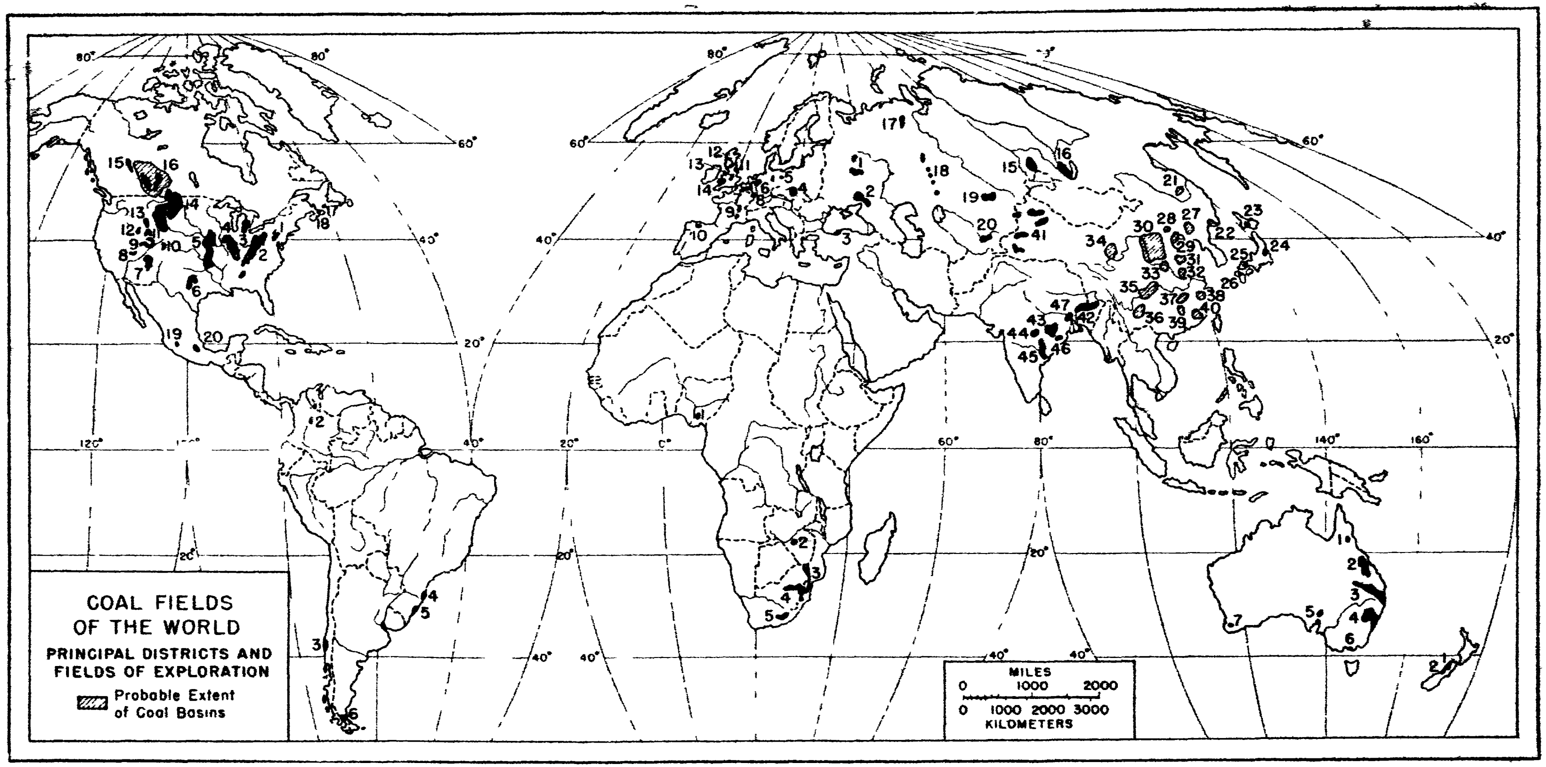
Coal production in Eurasia. There are four major areas of coal production in Europe: (1) Great Britain, (2) the Northwest Continental area, which includes northwest Germany and extends through the Netherlands and Belgium into northeast France, (3) the Silesian District of southwestern Poland, Germany, and Czechoslovakia, and (4) the Donetz Basin of southern Russia (see Illus. p. 368). Secondary centers are in the Saar district near Lorraine, the Moscow field, and in the smaller producing fields of southern France, Czechoslovakia, Hungary, and Spain. The United Kingdom and Germany have long been the two leading coal-producing countries of Europe. Although Germany mined the greater tonnage, over 50 per cent of her production consisted of brown, low-grade lignite of much lower heat value than bituminous coal. On the basis of importance to industry, therefore, the production of the United Kingdom equaled and sometimes exceeded that of Germany during the period prior to World War II.

The United Kingdom. The coal fields of Great Britain are in four principal areas (see Illus. p. 367). In the north the Scottish Lowlands west of Edinburgh furnish fuel and power for the industrial center of Scotland. To the south, in England, on the east side of Pennine range, are the well-known producing areas of Newcastle and Yorkshire, while on the west are the highly productive and industrialized areas that extend from Manchester to the Midlands, the region around Birmingham. In southern Wales is the well-known Cardiff field, which has the reputation of being the greatest field in the world for coal exports. England is favored in the high quality of her coal and in the wide distribution of her producing fields. These factors have been largely instrumental in bringing about the successful industrialization for which the United Kingdom has long been famous. However, mining conditions are becoming more difficult and costs therefore are becoming higher, thus giving rise to industrial problems which are not easy of solution.



Principal coal mining regions of northwestern Europe. Note particularly extensive coal basins from the Ruhr of Germany to the Sambre-Meuse of Belgium and France. The coal fields of England are largely on the flanks of the Pennine Range.

Coal is the basis of British industry and is the most important bulky export in British foreign trade. Since Britain has little water power and almost no petroleum or natural gas, she must rely upon coal as her chief fuel resource. The keen competition of other fuels which coal is meeting in all parts of the world is especially felt in Britain



Coal map of the world Shows principal mining regions in all the continents See legend below.

MAJOR COAL FIELDS OF THE WORLD

(see illustration above)

North America

1. Pennsylvania Anthracite region
2. Appalachian region
3. Northern Interior region
4. Eastern Interior region
5. Western Interior region
6. Southwestern Interior region
7. San Juan River region
8. Southwestern Utah region
9. Uinta region
10. Denver region
11. Green River region
12. Hains Fork region
13. Bighorn Basin region
14. Fort Union region
15. Peace River field
16. Alberta fields
17. Sydney field
18. Pictou field
19. Michoacan field
20. Puebla field

South America

1. Rio Pamplonita field
2. Santander field
3. Arauco field
4. Santa Catarina field
5. Porto Alegre field
6. Punta Arenas field

Australia

1. Mt. Mulligan field
2. Mackenzie-Dawson River field
3. Ipswich-Tawbo field
4. Newcastle field
5. Leigh Creek field
6. Wonthaggi field
7. Collie field

New Zealand

1. Westport field
2. Greymouth field

Africa

1. Enugu field
2. Mid-Zambesi-Warkie field
3. Limpopo-Lebombo field
4. Natal-Zululand field
5. Cape Province field

Europe and Asia

1. Moscow field
2. Donetz field
3. Zongouldack field
4. Upper Silesian basin
5. Central Germany Brown Coal fields
6. Ruhr Coal basin
7. North France-Central Belgium-Netherlands field
8. Saar basin
9. Central Plateau fields
10. Oviedo field
11. Northumberland-Durham field
12. Scottish Coal fields
13. Yorkshire fields
14. Welsh fields
15. Kuznetsk field
16. Irkutsk field
17. Pechora field
18. Ural fields
19. Karaganda field
20. Uzbek field
21. Talaya field
22. Vladivostok field
23. Ishikari field
24. Fukushima-Ibaragi field
25. Yamaguchi field
26. Fukuoka field
27. Southern Liaoning region
28. Central Jehol region
29. Northeast Hopei region
30. Shansi-Shensi region
31. Central Shantung region
32. N. Kiangsu-S. Shantung region
33. N. Honan region
34. W. Kansu region
35. E. Szechwan region
36. E. Yunnan region
37. E. Hunan-W. Kiangsi region
38. S. W. Chekiang region
39. S. E. Hunan region
40. S. Fukien region
41. Sinkiang region
42. E. Himalayas, Assam, and Bengal fields
43. Central India field
44. Satpura basin
45. Hyderabad field
46. Orissa field
47. Bihar field

because of the large number of workmen who suffer by curtailment of coal production. This competition was foreseen by British industrialists several decades ago and was responsible to a considerable degree for the energetic expansion of British capital and British industry into other areas of the world where reserves of petroleum were known to exist.

FRANCE AND BELGIUM. In northern France and extending across Belgium into southern Netherlands and the Aachen region of Germany are extensive deposits of coal that vary in rank from high-grade bituminous to anthracite. These deposits provide the greater part of the supply of coal produced in these three countries and are of prime importance industrially. The beds are thick, faulted, and some steeply inclined. Although the quality of the coal is good—much of it of coking quality—the mines are deep and the structural conditions render mining costs high. The world's deepest coal mine is said to be in operation in the Namur district of Belgium at a depth of over four thousand feet. Within France, smaller fields are located in the southern part of the country on the flanks of the Central Plateau. Their industrial significance, however, is relatively small.

GERMANY. Germany normally has ranked second to the United States in quantity of output. The country is known to have huge reserves of coal varying in rank from low-grade lignite to high-grade bituminous. Prior to World War II, the most important districts were the bituminous coal fields of the Ruhr and Aachen, the Saar in northwest Germany, and the Silesian fields in the southwest. The lignite, or brown coals, are found extensively in Prussia, Saxony, Hess, and Bavaria, with more than 50 per cent of the output ordinarily being produced in Saxony.

The Ruhr is a continuation of the coal measures farther west; the strata are gently folded and but slightly faulted (see Illus. p. 367). The individual beds are of moderate thickness, but at least 32 coal seams have been exploited within the Ruhr district to an aggregate thickness exceeding 190 feet of coal. The coal is of high volatility, is low in ash, and is of excellent coking quality. The Ruhr district therefore has long been the foremost center of Germany's heavy industry. (See also map, p. 368.)

The Silesian field, now in southern Poland, ranks second only to the Ruhr. The coal there is known as a good steam coal of high coking quality. The gently inclined beds at shallow depths provide conditions favorable for low-cost mining operations, and these factors together with increasing market demands have given rise to a rich industrial area in that section.

THE BROWN COAL DEPOSITS—LIGNITE. The brown coal beds of central and northwestern Germany are extensive and of great thickness, more than 300 feet having been reported in some places. Eighty to 85 per cent of the production is carried on through open-pit mining at an exceptionally low cost per ton. The importance of the brown coal resources to the industrial life of Germany can hardly be overemphasized. The lignite, ordinarily known as a low-grade fuel, is made into briquets for household use, and it provides the raw material for the manufacture of synthetic gasoline and the basis for much of the development of the German electrical and chemical industries.

The coal resources of Germany have given rise to some of the most intricate of postwar problems. The disposition of the Ruhr coal field, together with the policies to be pursued with respect to the future of the German heavy industries and their chemical industries, have served to arouse such differences of opinion among the nations victorious in World War II that settlement has been delayed to a degree which many have considered contrary to the best interests of the nations themselves and of Germany. In time these problems will undoubtedly be solved and some fairly equitable outcome may be expected. It seems clear, however, that stagnation resulting from disagreement cannot be conducive to the economic welfare of any peoples, whether victors or vanquished, and that the general welfare of all of Europe and likewise of much of the world can best be facilitated through industrial production operated for the output of goods of all kinds needed for peacetime use.

THE SOVIET UNION. The reserves within the tremendous area of the Soviet Union are known to be large (see Illus. p. 368). So far as is known, however, it appears that at least 80 per cent of the Russian reserves are in Siberia, where the quality ranges from lignite to anthracite. In general, these outlying deposits have been but slightly exploited to date. The Donetz Basin, north of the Sea of Azov, is the most fully exploited of Russia's coal regions. There mining encounters folded and faulted beds; while operations are expensive the coal is of high heat value and much of it is of excellent coking quality. During the past decade the Donetz Basin has not been able to furnish all the coal needed, but it has provided the coking and steam coal used in reducing the iron ore from the near-by Krivoi Rog area, a factor that made exploitation profitable, thus promoting industrial development in this part of Russia.

Coal deposits in the Moscow area are rather extensive but the coal is not of high quality and has been but slightly exploited. The centers east of the Urals, particularly in the Kuznetzk area, have been developed recently into large-scale operations. Russia's handicap is that the known supplies of coking coal are not large and are quite remote from the known iron ore deposits, although both are scattered through the vast distances of Siberia.

CHINA. Huge deposits have been reported to exist in China, and early estimates placed the reserves there on a par with those of the United States. However, later data have been much lower than those published earlier (see Illus. p. 368). The deposits are widely scattered, but the better qualities occurring under relatively favorable mining conditions have been exploited in Manchuria and in northern China, with the result that this section of the country ordinarily produces two-thirds of the entire output. Although the coals of South China are generally of lower quality, local areas have high-grade coal which, in most instances, occurs in rather steeply folded structures which give rise to difficult mining operations. Nevertheless, the retarded development of coal mining in China may be attributed chiefly to the unsettled military and political conditions of the past, because it is known that the coal beds are extensive and the potentialities of exploitation great.

JAPAN. Many small coal fields occur in Japan, particularly in Honshu and Hokkaido, where quality varies from low-grade bituminous to high-grade coking coal. The reserves are estimated to be not more than 1 per cent as great as those of China. Despite the energetic enterprise of the Japanese and up-to-date mining methods, the coal fields have been found inadequate to serve the industrial needs of the country, and hence imports have been necessary in the past and unquestionably will be necessary in the future if the industrial life of Japan is to prosper.

INDIA. In northern and central India (see World Map, page 368) the reserves are estimated to be at least four or five billion tons of easily accessible, high-quality coal, a third or more of it being of coking quality. While smaller fields are found in other parts of the country, the Bihar and Orissa fields are the most important and the most promising of continued exploitation in the near future. The iron ore and coal are within easy reach of each other, a condition which seems to warrant the expectation of rapidly increasing industrialism in northern India.

Coal production in other continents. The production of coal by the principal countries of the world, as shown by the graph, page 372, shows clearly that the Northern Hemisphere holds almost a monopoly in this line. South America has some known reserves which are widely scattered and little exploited. Inasmuch as coal can be imported at relatively low cost and the petroleum industry is expanding, the near future does not seem favorable to important development of the South American coal industry, even if further exploitation should reveal extensive deposits in various sections of the continent. At present, Chile and Brazil are the only countries with substantial output, although coal is known to exist in a number of other areas.

There has been considerable development in South Africa, but the demands have not been sufficient to give rise to any great industrial progress, and hence only deposits found nearest local needs have been exploited in any considerable degree. The same may be said of Australia, because there development is handicapped by lack of both labor and markets. Largely because of the youthfulness of the country, industrialism has not reached a stage of development common in some of the older nations. As demand increases, the coal-mining industry of Australia as well as of South Africa may be expected to keep pace, but there seems little prospect of any rapid progress in the near future.

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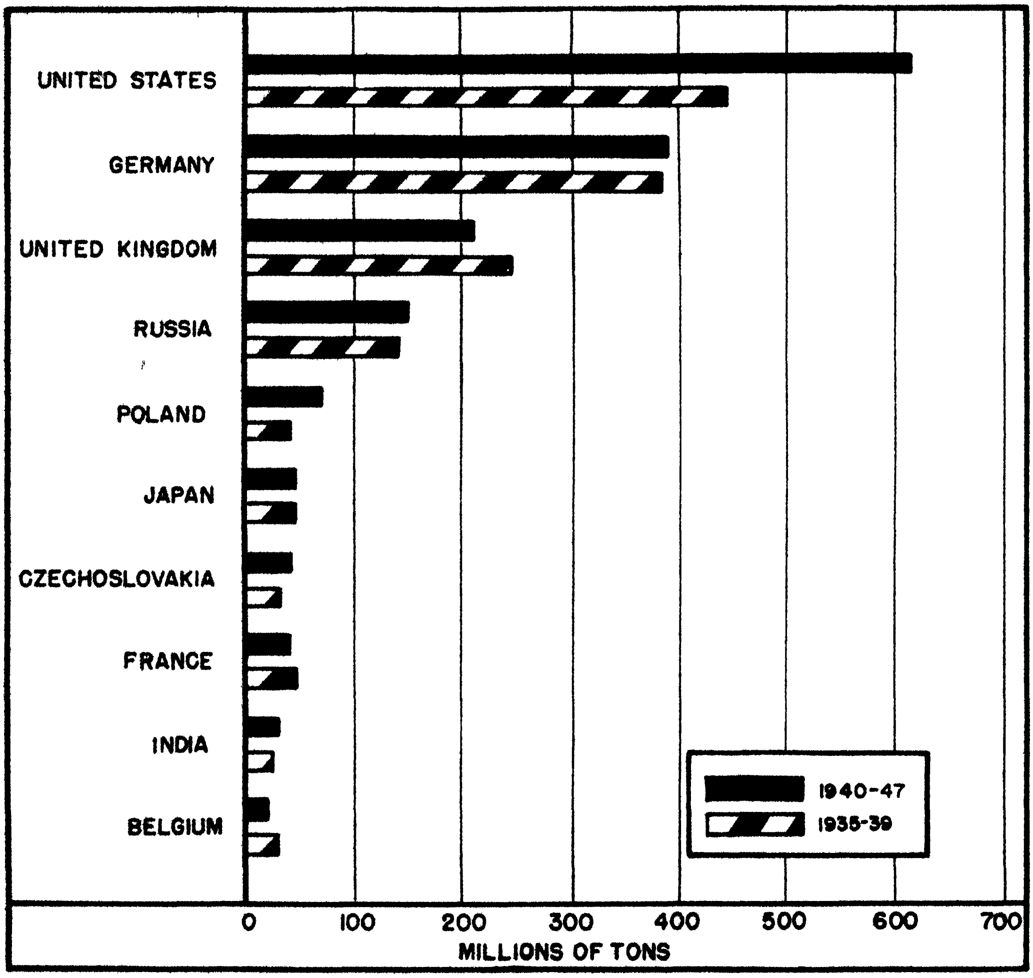

Production of coal, principal producing countries of the world. Data incomplete for Germany and the countries behind the "iron curtain," but graph is based on best estimates available.

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Chapter Twenty-two

THE PETROLEUM INDUSTRY—A MODERN INDUSTRIAL GIANT

ALTHOUGH ITS RISE TO A POSITION OF industrial necessity has been recent and of meteoric speed, petroleum has long been recognized as a mineral oil of use to man. Tar from petroleum seepages is reputed to have been used in constructing the tower of Babylon, to have been used in burial procedures by the ancient Egyptians, and to have been responsible, in a measure at least, for the successes of the Phoenicians in sailing their light craft in widespread operations in the Eastern Mediterranean. The use of petroleum as an ointment was recognized by the people of ancient Mesopotamia long before the beginning of the Christian era. In the New World it was used by the Indians of Pennsylvania and New York for medicinal purposes. Its use in industry, however, awaited the discovery of large quantities of petroleum obtainable only by drilling through considerable thicknesses of hard rock. To Colonel E. L. Drake must be given the distinction of being the first to inaugurate the needed procedure.

Early discoveries of petroleum. During many centuries oil seepages had been known to exist in various parts of the world, and their possibilities for heating and lighting had been suggested by a few persons long before the nineteenth century. Marco Polo in the thirteenth century was reported to have noticed oil seeps at the southern base of the Caucasus. Yule, in his "Travels of Marco Polo," refers to a fountain there from which "oil springs in great abundance. This oil is not good to use with food, but 'tis good to burn, and is also used to anoint camels that have the mange." Several centuries later, oil from seepages in some places was found adaptable for use in lamps. This use led to a growing demand for oil because of the scarcity of animal or vegetable fats suitable for use as illuminants. In order to obtain larger production, hand-dug wells were attempted. In most cases these met with indifferent success, but in Burma they early yielded satisfactory results. Thus, Rangoon Oil became a significant article of commerce in London early in the nineteenth century. Hand-dug wells were by that time also numerous in Romania. Before there was an American petroleum industry, oil refining to obtain kerosene and lubricants had begun.

Although there was early knowledge of the presence of oil in western Pennsylvania, its uses were not well understood and demand grew slowly. Before the middle of the nineteenth century, however, the use of oil for ointments, and to some degree for use in lamps, had expanded to such an extent that the price for the small available supplies had reached phenomenal heights. This condition attracted attention, and companies began to be formed for the exploitation of the "rock oil." As it was an entirely new field, all the techniques of exploitation and refining had to be learned. Drilling through hard rock was the first problem to be solved.

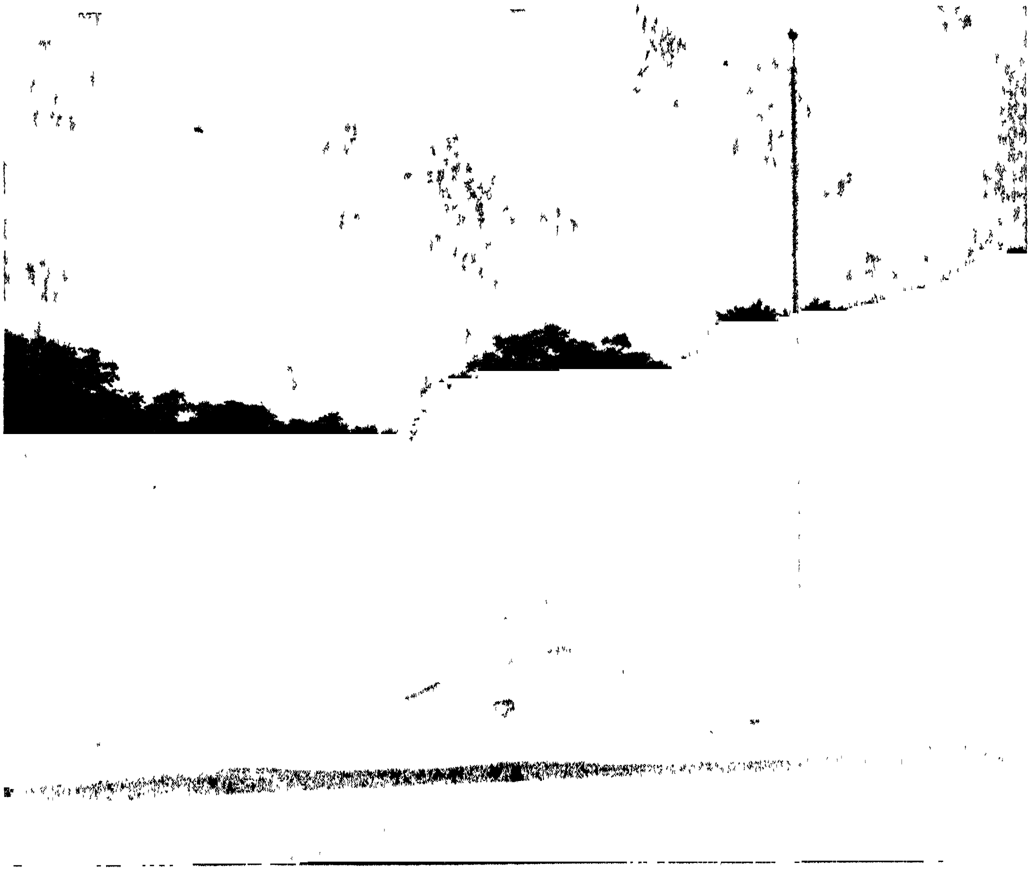

Photo Courtesy J. Willard Miller, Pennsylvania State College

Drake Memorial Park, Titusville, Pennsylvania. The Drake well is marked by a capped tube at the base of the flag pole. Monument dedicated to E. L. Drake is at left of the pole. Photo by Nelson's Studio, Titusville, Pa.

In 1859 near Titusville, Pennsylvania, Colonel E. L. Drake rigged up a crude drilling apparatus based upon the principle of crushing the bedrock into minute particles by successively raising and dropping a heavy iron rod equipped at its lower end with a hard, sharp bit. By this trip-hammer method, he drilled his well to a depth of 69 feet, obtaining a yield of about 25 barrels of light oil per day.[1] This was the first well to be drilled mechanically for the express purpose of obtaining petroleum (see Illus. below). The exact location of the well was chosen on the basis of seepages found near by along the banks of Oil Creek. At first the petroleum produced by the discovery well was sold at over $20 per barrel, but soon other wells were drilled and so much was obtained that prices collapsed. These early incidents marked the first instance of "boom and bust" in the petroleum industry. Through a long and active career Drake lived to see the industry become an industrial giant, but he died a poor man—a fate not uncommon to the pioneer.

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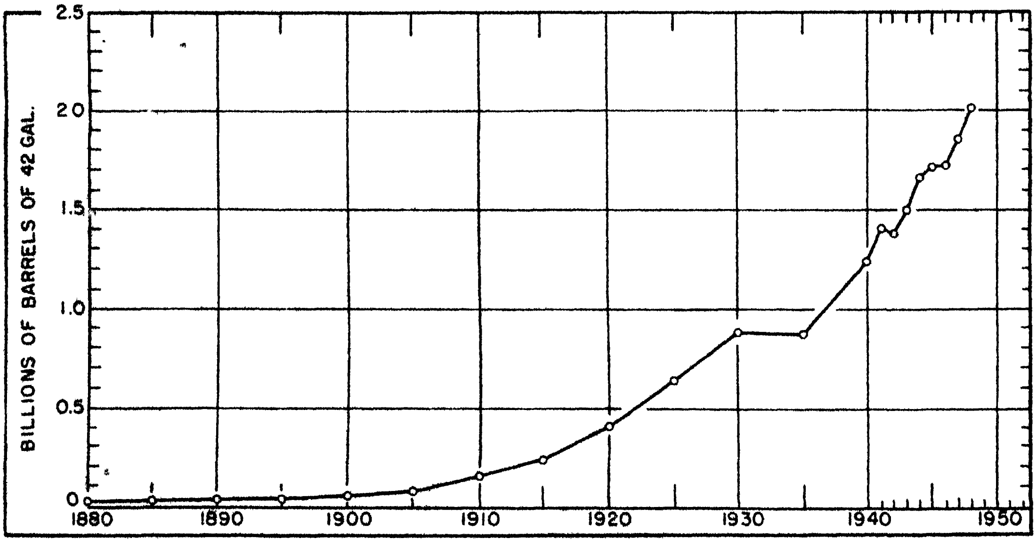
[1] The "barrel" of petroleum is a commonly accepted unit of measurement and has a content of 42 gallons.

Economic importance of petroleum. The art of drilling for petroleum through solid rock, thus inaugurated in western Pennsylvania by Drake, not only brought a flood of oil into reality but marked the beginning of a new industry with its numerous attendant problems. Inasmuch as wooden barrels, the only equipment then available, were inadequate, new means of transportation had to be devised. Refining was merely a simple distillation process, and only the fraction which became known as kerosene was deemed to be of marketable value. Even the kerosene lamp had to be devised so as to avoid danger of explosion. Internal combustion engines were still in the dream stage. Such was the beginning of the oil industry here and abroad.

As may readily be observed from the graphic illustration, above, the production of petroleum increased steadily but not rapidly until after the close of the nineteenth century. Since that time, however, petroleum production and the development of industries attendant thereupon have proceeded at a continually accelerated pace in the United States and abroad. From the beginning of the industry from "scratch" in 1859 it has grown to represent an investment in the United States variously estimated at seven to twelve billion dollars. Yearly production increased from a few barrels in 1859 to 63,621,000 barrels in 1900 and then to 2,051,000,000 barrels in 1948, with no indications as yet that the upward trend is slackening. From the viewpoint of value of output, petroleum has assumed rank as one of the three or four most important commodities produced by the United States either in the realm of minerals or of agricultural crops (see Illus. p. 377).[2]



Petroleum production in U. S. A. since 1876. How does one account for the flattening of the curve during the 1930-1935 period?

Industrial significance. The expanding production of petroleum has of course been due to the varied uses to which its products are adapted—uses which have, in turn, resulted from the chemical discoveries which have been made and from the instruments, machinery, and general equipment which science and engineering have brought into action. Thus we have a legion of secondary industries that have developed in connection with the production of petroleum. In the realm of transportation, industries which now have been organized into separate corporations include those of constructing and managing pipe lines, tank cars, and ocean tankers, while in the realm of manufacture they include industries producing Diesel engines, automotive engines, jet planes, iceboxes, chemicals, and drugs. All these and many others have given rise to great industrial plants providing demands for labor ranging through the whole category from unskilled to highly scientific and, within the realm of management, from humble foremen to top executives. The petroleum industry now includes some of the greatest corporations in the world, but it is not limited to such, for it also includes literally thousands of smaller corporations which may properly be termed small businesses. This whole structure, however, has become so intimately interwoven into our fabric of economic life that whatever affects its welfare, favorably or adversely, has its repercussions upon the well-being of all. Petroleum has become an essential business factor in peacetime and a military necessity in time of war.

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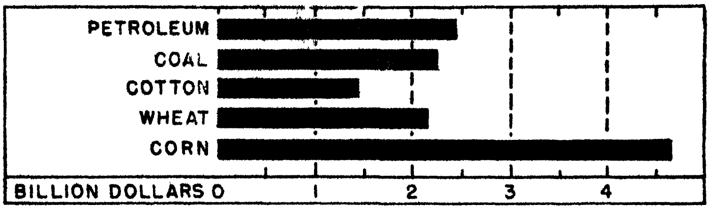
[2] In 1948, the total number of wells drilled in the search for oil and gas was 39,778. Of this number 22,585 were oil producers, 2,897 were gas wells, and 14,296 were dry holes, producing neither gas nor oil.

With recognition of some of the factors that have been involved in the petroleum industry from the earliest period to the present, and with appreciation of the position now reached, we may well raise such questions as: Under what conditions does petroleum occur? To what processes must it be subjected to prepare it for the varied uses now demanded of it?

Properties of petroleum. Petroleum means literally *rock oil,* a term which was given because the seepages were found in rock and some people believed that the oil was something that was oozing out as it was being produced in some mysterious manner immediately within. Technically, however, petroleum has been defined as "an inflammable mixture of oily hydrocarbons that exudes from the earth or is pumped up."[3] By hydrocarbons is meant a group of compounds consisting essentially of hydrogen and carbon chemically combined in varying proportions. Petroleum is a mixture of liquid, gaseous, and solid hydrocarbons, of which the latter two are wholly or partly in solution in the first. This mixture may contain so many different kinds of hydrocarbons that the abilities of the chemist must be invoked in order to recognize or separate them.

The large number of different mixtures gives rise to numerous kinds or grades of crude petroleum. Light oils have low percentages of carbon and high percentages of hydrogen, whereas in the heavy oils the reverse holds true. Therefore, light oils, such as the gasolines and light naphthas, are usually much richer in the lighter hydrocarbons than are the heavier fuel oils. Since the lighter hydrocarbons are in greater demand, it may be said that in a general way



Values of five leading commodities produced on farms, by oil wells and in mines of the United States in 1946. Prior to that year the value of coal had been greater than that of petroleum.

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[3] W. H. Emmons, *Geology of Petroleum,* McGraw-Hill Book Company, New York, Chapter I.

the value of petroleum increases as its density decreases.

Petroleum varies in color from light straw to almost black. Some kinds are greenish, others amber-colored, and some even rich wine red. In general, high-grade crude is light-colored and greenish, whereas the heavier grades are brown to black. With respect to the residue which results upon evaporation or refining, crude petroleum is classified into three groups: paraffine base, asphalt base, and mixed-base oils. The paraffine base oils are ordinarily lighter and more fluid than are those with asphalt base.

The density is expressed in terms of specific gravity or in terms of its equivalent on the Baumé scale. Specific gravity of crudes varies from 0.77 to 1.00, but ordinarily it ranges between 0.82 and 0.94. The direct specific gravity scale is open to the objection that it deals with fractions and that the numbers are neither read nor remembered easily. Therefore, an arbitrary scale known as the Baumé is employed and the densities are usually designated in terms of Baumé rather than in terms of specific gravity. On the Baumé scale specific gravity 1.00 is read as 10°. Oils are tested by means of hydrometers constructed for use in liquids lighter than water, and therefore the readings are given in integral numbers larger than 10. Oils nearly as heavy as water have readings only slightly larger than 10°, whereas those which are light have much higher readings. In common trade usages, crude oils which give a Baumé test below 20° are known as *heavy*, whereas those which test above 30° are *light* oils.

Fundamental aspects of petroleum refining. Petroleum refining has been improved to such an extent in recent years that it can no longer be termed a process of mere distillation; it has developed into a chemical industry of the first magnitude. Formerly it was generally understood that "gasoline was gasoline," but now we know that there are various grades of gasoline, each differing essentially from the others. Gasolines of specific qualities now are supplied for use in motors operating under different mechanical and weather conditions. The improvements in the processes of refining to obtain higher quality products have been made hand in hand with progress in making more complete use of crudes formerly deemed undesirable. Heavy oils can now be converted into lighter oils, the basic principle of the process being to heat the oil under pressure in the presence of free hydrogen. Through chemical absorption, the ratio of the hydrogen to the carbon is increased and the petroleum converted into a lighter grade, the quantity of gasoline obtainable being increased thereby. This is the fundamental principle underlying the *hydrogenation* process. On the other hand, some crudes have gases associated with them known as wet gases that are too light for practical use, in which case the problem is one of decreasing the ratio of hydrogen to carbon in order to manufacture a somewhat heavier product than is indicated by the light crude and associated gases. This likewise has been accomplished through changed methods in chemical refining and is known as *polymerization.*

Thus, through the processes of refining referred to as *cracking* and *hydrogenation*, heavy oils are converted into lighter oils, and through the opposite type of process, known as *polymerization*, the extremely light crude and associated gases may be converted into heavier products. In all cases the processes give rise to an increased percentage of output of gasoline, the product most in demand. Through these and other advances in refining, the percentage of gasoline extracted from the crude has been more than doubled during the past two or three decades. Had this not been accomplished, we would now be faced with gasoline shortages in the United States, notwithstanding the enormously increased production of crude.

Although fuels, particularly kerosene and gasoline, were the first products sought by refining crude oil and they still hold the spotlight of popular appeal, they do not tell the whole story. Petroleum, through the developing techniques of refining, has become a basic raw material for a great variety of chemical products varying from asphalt to medicinal drugs. Among such products none is more vital to industry than the lubricants. In fact, some scientists have been concerned more about threatened shortage of lubricants than of motor fuels. Should petroleum reserves be depleted, the problem of obtaining liquid fuels from sources other than petroleum appears more readily solvable than does the problem of obtaining high-grade lubricants. The refining industry has succeeded marvelously in providing lubricants from petroleum whereby nearly all types of machinery may have their individual requirements met. The recognized efficiency of modern machines in agriculture, industry, and transportation must be attributed in large measure to the high-quality lubricants now available.

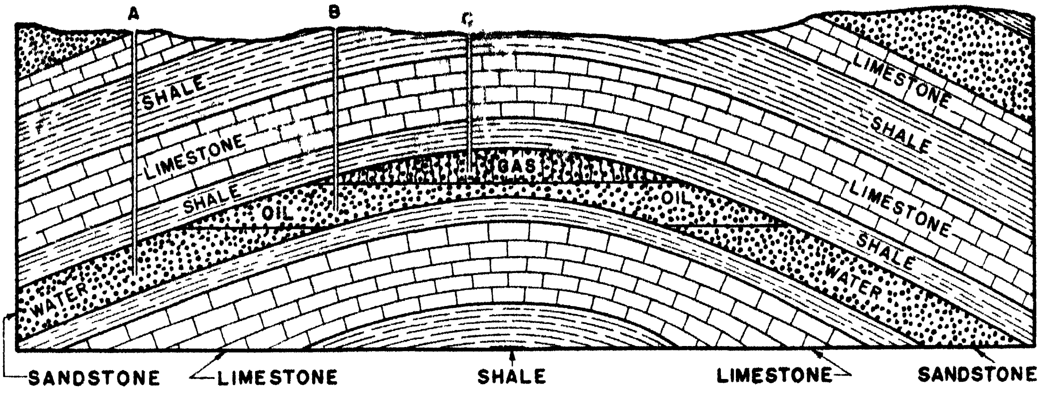
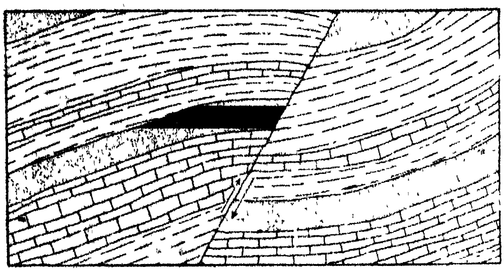


Diagram to illustrate an oil bearing anticline. In this case note that shale is the cap rock and sandstone is the reservoir rock Free gas has collected at the apex of the structure. Wells A, B, and C have tapped the reservoir rock with different results.

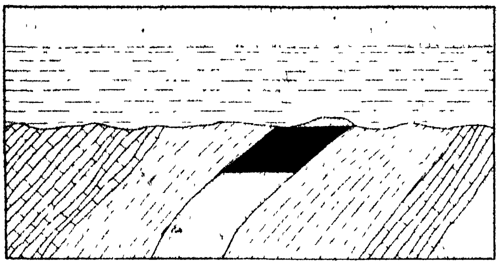
Mode of occurrence. Most of the petroleum of the world occurs in sedimentary rocks, especially sandstones, conglomerates, shales, and limestones. Open-textured sandstones are perhaps the most common reservoirs, although in many cases notable production has been obtained from porous or cavernous limestones. Petroleum is but rarely found in igneous rocks, and in the few known cases the migration of the petroleum from sedimentaries into the igneous rocks has been clearly proved. It usually occurs in strata varying in structure from steeply folded and faulted to almost flat-lying. Anticlines are perhaps the best-known folds favorable for petroleum accumulation (see Illus. below). Where that type of structure is found in petroliferous areas, natural gas may occur in the apex of the anticline, petroleum in the upper flanks, and water at the lower levels. This sequence, however, does not necessarily follow, because in petroliferous areas it is often the case that no free gas is found in the apex, even when the petroleum exists under pressure, because the gas in a large number of cases is dissolved within the liquid petroleum found in the interstices of the reservoir layer.

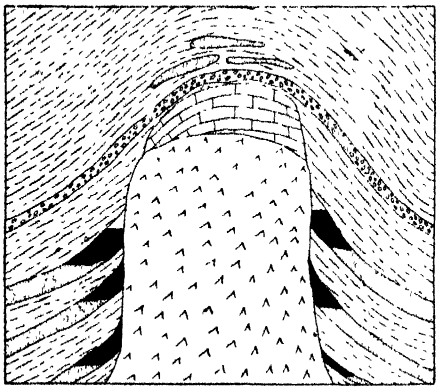
The general sequence, however, of water, oil, gas, or gas dissolved in the oil is the commonly found condition. The necessary structural conditions are that there must be present (1) petroliferous beds from which the petroleum has been derived by natural distillation in minute droplets, (2) a reservoir rock for the accumulation of the oil and gas particles, and (3) a cap rock which prevents escape or dissipation of the petroleum and gas. The reservoir rock sealed by a cap rock gives rise to what is usually recognized as a *petroleum trap.* Such traps occur under various structural conditions, some of which are graphically illustrated by the three diagrams below.


TRAP FORMED BY A FAULT

(A) Diagram illustrating petroleum accumulation in a sandstone "trap" caused by a fault in tilted strata. A *fault* is a structure wherein strata have been broken and displaced. The arrows indicate the vertical displacements in this case.

(B.) A petroleum trap sealed by flat-lying rock sedimentary deposited over an ancient, eroded surface of steeply pitching beds. The upper flat-lying layers are fine-grained shales at the base which prevent the oil and gas from escaping upward.


UNCONFORMITY SEALS END OF OIL-BEARING FORMATION

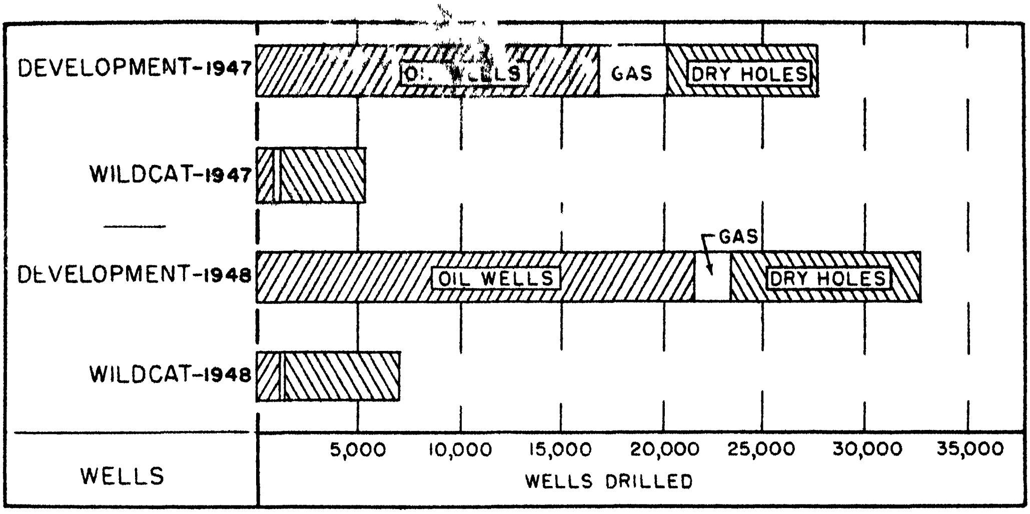

OIL TRAPPED AGAINST SIDES OF SALT PLUG

(C.) Diagram to illustrate salt plug or dome structures with petroleum reservoirs in tilted strata sealed with the core Structures of this kind are common in the Gulf Coastal Plain but not all are petroliferous.

Distribution of petroleum production in the United States: THE APPALACHIAN PROVINCE. The first great oil field to develop on a large scale was the one that extends from southwestern New York through Pennsylvania and eastern Ohio and southward into Tennessee (see Illus. p. 382). Oil had long been known to exist in seepages along some of the creeks of northwestern Pennsylvania, and for many years the crude had been skimmed from the surface of the waters and used by the Indians as an ointment and for medicinal purposes, a practice that was also taken up by white people, when they came into that section of the country. In some places people who had tried to dig wells for water had penetrated oil-soaked muds and sands, but the knowledge of petroleum possibilities was then so slight that they considered themselves unfortunate because the oil had ruined their chances of obtaining good drinking water.

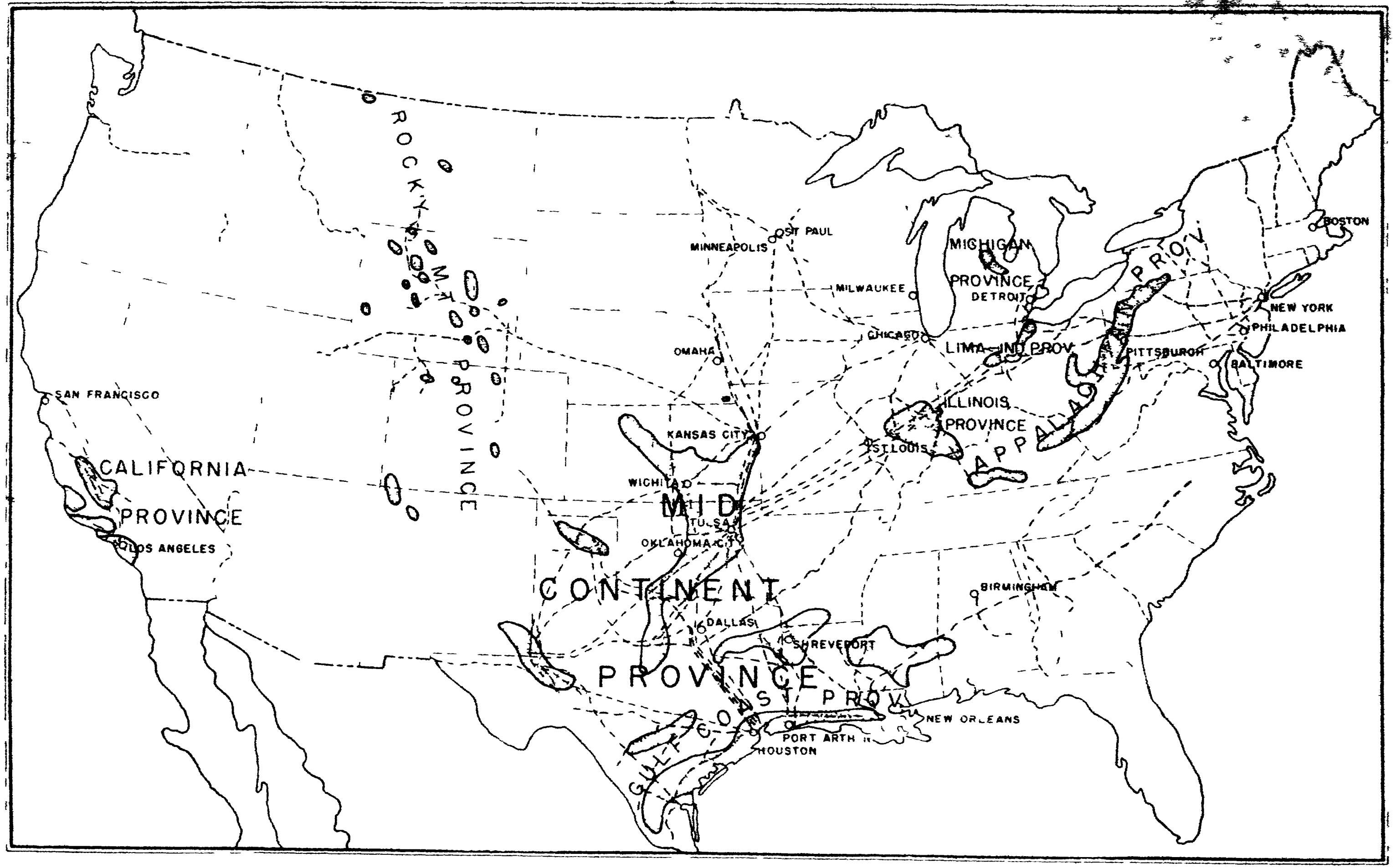
With the success of Drake's discovery well in 1859 all this was changed and a rush of drilling followed. Within a year several hundred wells had been drilled; most of them were dry holes, but some were fairly good producers. In June, 1861, the first flowing well was brought in with a daily output of over 300 barrels of oil. In September of the same year the first "gusher," flowing 2,500 barrels per day, was struck. Such results were wholly unexpected, and people were then willing to believe anything. The first oil boom was on, and the buying interest in proposed wells became a public craze. The boom, however, was of short duration because the market soon became flooded with oil, and the price dropped from above twenty dollars per barrel to almost zero. Thousands of barrels are reported to have been sold at five cents per barrel. Thus, within three years after the discovery well, the young petroleum industry had experienced the thrill of boom conditions and the gloom of depression. Thereafter, however, the industry steadied and Pennsylvania oil for many years furnished the foremost supply of crude for an ever-growing American industry.

An early peak in production was reached in 1891, when more than 33 million barrels of oil were obtained. This was followed by a slow and persistent decline, but a revival of production through deeper drilling, improved methods of pumping, and the discovery of new pools in the southern part of the province raised the total again to a second peak in 1943, when more than 35 million barrels were produced. The Appalachian Province is notable for its long life and its relatively steady production. However, some of the older portions now produce, on the average, less than one-fourth barrel per well daily, and the average production of all wells in Pennsylvania now operating is less than 0.6 of a barrel per day. The recent trend has therefore been toward slight decline; one cannot say now how long that may remain a characteristic (see Illus. p. 384).

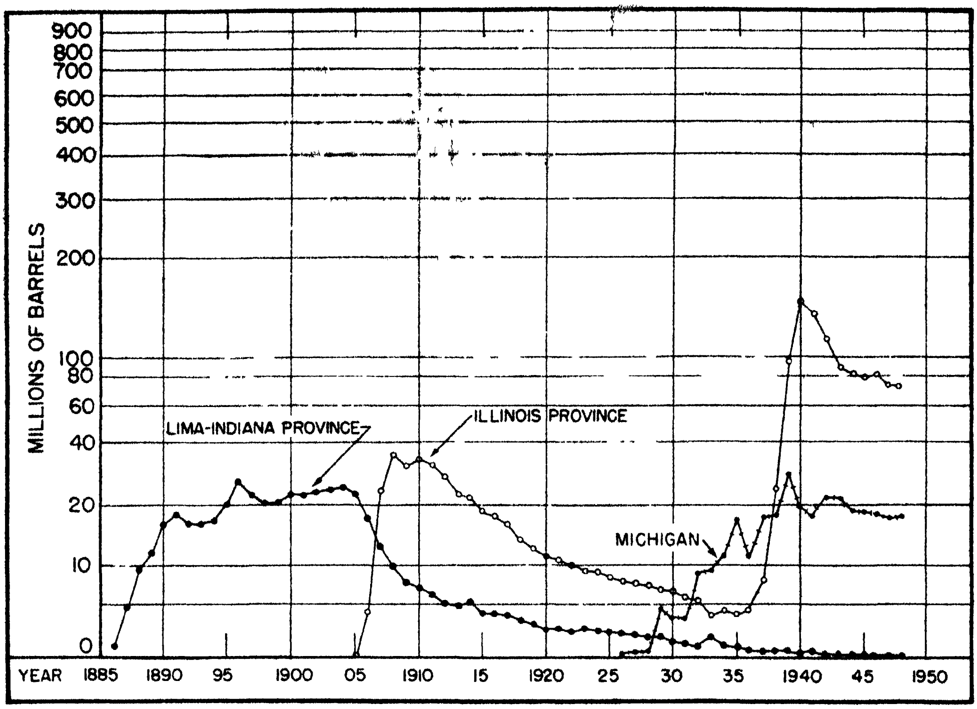


"Development" wells are those drilled in or near proven producing areas. "Wildcat wells" are exploratory wells drilled in territory not proven. How did the *percentages* of dry holes in the wildcat groups compare with the percentages in the development groups?

The oil of the Appalachian fields is high grade, ranging from 40° to 45° Baumé in the eastern portions of the province to around 30° to 35° Baumé in the western. It is a paraffine-base crude characterized by a low percentage of residue, and it is free of sulphur, is easily refined, and is rich in the light constituents as well as in high-



Map of the petroleum provinces of the United States and the principal petroleum pipe lines grade lubricating stock. These favorable properties cause the oil from this province to be ranked exceptionally high, and the term "Pennsylvania-grade" has come to stand as representative of the world's best oil. Because of its high quality and its nearness to the great marketing centers, it is the highest priced crude in the United States.

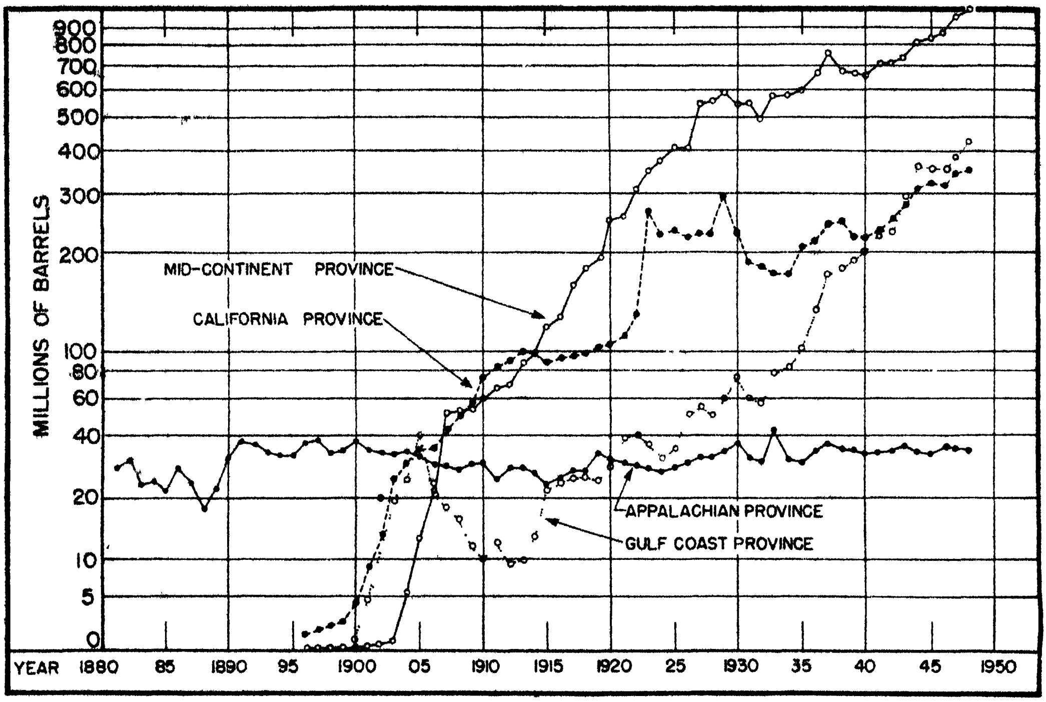


Annual production of the Lima(Ohio)-Indiana, Illinois, and Michigan petroleum provinces since 1885. In what year did each reach its apparent peak of production?

The Ohio-Northeast Indiana Province. The Ohio-Indiana Province extends in a general southwesterly direction from near the west end of Lake Erie into eastern Indiana (see Illus. p. 382). The province lies on the west flank of the Cincinnati anticline, the crest of which separates it from the Appalachian Province to the east. Production began in 1884, reached its maximum in Ohio in 1896, and in Indiana in 1904. Since then decline has been persistent, and no revival of production is likely. The oil is of paraffine base and is fairly light, averaging 30° to 35° Baumé. It is somewhat difficult to refine because of its sulphur content, but improved methods of refining have now largely overcome this difficulty. Notwithstanding the favorable location of the province and the relatively high quality of the oil, the crude usually sells considerably below that of the Appalachian fields.

The area has been quite thoroughly exploited and although commercial production is likely to continue for a number of years, it now seems that the limits of the producing acreage have become well defined. The declining trend indicates that complete exhaustion of the available oil is but a matter of a comparatively short time (see the graph above).

The Michigan Province. Michigan was not listed separately in the statistical record until 1925, although some oil had been produced earlier. From 1925 to 1929 the annual output increased from 4,000 barrels to more than 4½ million barrels, and this increase, sharp as it was, was virtually continuous until 1939, when the peak of Michigan production was reached at nearly 23½ million barrels (see Illus. p. 383). For several years the production held fairly steady, but more recently a decline has set in which may indicate a persistent trend. It is too early now to forecast definitely because active drilling is still in progress and the trend may change with any year. Nevertheless, on the basis of the record to date, it does not appear that Michigan is likely to reach the large production that has characterized most of the major fields of the United States.



Annual production of the Appalachian, Gulf Coast, Mid-Continent, and California petroleum provinces since 1880. Semi-logarithmic scale. When did the pronounced upturn in production in the Mid-Continent begin? What is the unique characteristic of the production curve of the Appalachian province?

The Illinois-Southwest Indiana Province. The petroleum-producing area of Illinois is mostly in the southern part of the state, the field extending into the adjacent portions of Indiana and Kentucky. Production began in 1905 and expanded rapidly to 33 million barrels in 1910, after which there was a slow and steady decline to less than 5 million barrels in 1935. This was followed by discovery of new fields to the west and south of the old fields in Illinois, which caused a spectacular increase in production to more than 152 million barrels in 1940. Since that date, however, the output dropped rather rapidly to about 80 million barrels, a decline of nearly 50 per cent in 7 years. Active exploration through drilling is continuing, and should further pools or fields be discovered, the trend may be reversed. Present evidence, however, does not justify confidence in recovery that will reach the peak of 1940.

The petroleum of Illinois is mostly of paraffine base, tests above 30° Baumé, is sulphur free, and is easily refined. However, since the content of natural gasoline is relatively low (only about 15 to 20 per cent), the crude has a market value below what might be expected for oils of such high gravity.

The Mid-Continent Province. Included

within the Mid-Continent Province are the petroleum-producing fields which extend from near Kansas City southward across Kansas and Oklahoma into Texas and thence eastward across northern Louisiana and southern Arkansas (see Illus. p. 382). Comprising the fringes of this vast area are the fields of central Kansas, the panhandle areas of Oklahoma and Texas, and the more recently discovered areas of western Texas and southeastern New Mexico. Thus defined, the province is by far the largest, most productive, and most important oil-producing area in the world. Large-scale commercial development began about 1906. Since then, production has mounted steadily, year by year, and apparently the maximum output has not yet been reached (see Illus. p. 384).

The Mid-Continent Province produces practically all grades of oil: some have paraffine base, some asphalt base, and still others mixed base. Some are almost as heavy as water, while others are as light and high grade as those of Pennsylvania. The complexity of structural conditions, different sources of origin, and vast extent of the province are responsible for the pronounced diversity in the occurrence and in the quality of the oils (see Illus. p. 379, 380, and 388). The petroleums from the shallow wells south of Kansas City, for example, are heavy, of asphaltic base, low in gasoline content, and of little lubricating value. On the other hand, those from the deeper sands at Augusta, Kansas, or Cushing, Oklahoma, are light, 35° to 40° Baumé, and contain a high percentage of natural gasoline and light lubricants. Such extremes of quality result in a wide range of prices for Mid-Continent petroleum.

The Mid-Continent Province is noted for the wide diversity of capital interests represented. Since it was the meeting ground of east and west and north and south, it was natural that capital from all of these sources should become interested in large-scale development there and, as a result, more different companies are exploiting oil in this province than in any other area in the world. These companies range all the way from those of world renown to those owned by a few people in some county or town. Contrary to popular opinion, no monopolistic condition prevails. Production, transportation, refining, and marketing are all on competitive bases, and the only semblance of any general agreement by these varied concerns is the movement toward limiting production to legitimate market demands. Even such agreements are subject to review by state conservation authorities and by the national government on the basis of agreements voluntarily entered into by the parties concerned. Continued overproduction in the United States during a period of years led many to favor voluntary control of output as a conservation measure, whereas in earlier years any arbitrary curtailment of production would have raised loud and long protests in many sections. Recent developments have convinced people that production in proportion to a reasonable demand makes possible the highest prosperity for all and that long-sustained production at a rate greater than the market can absorb is unsound economic practice and wasteful of a great natural resource.

While the potential production of the Mid-Continent Province is enormous, the reserves are not inexhaustible. That the province will continue for some time to be the major producing area of the United States seems certain, but the actual amount in reserve necessarily decreases as exploitation increases. Oil production is a mining activity, and oil taken out is not replaced. In time, even the great Mid-Continent Province must face declining output.

THE GULF COAST PROVINCE. The Gulf Coast Province includes the producing areas of the Coastal Plains of Texas, Louisiana, and eastward to Florida. In recent years considerable production has been attained in southern Mississippi, and a few successful wells have been drilled in the coastal plain of Alabama and Florida. Production in this province began in 1900 and rose rapidly to its first prominent peak in 1905, since which time declines and revivals have followed in almost rhythmical sequence. The province now ranks second in the United States, and there is good reason to believe that important output will continue for a long time (see Illus. p. 382).

The oil occurs in association with rock uplifts or domes. The early discoveries were made by drilling on low domes which appeared as hills rising a few feet above the surrounding flat plain. In recent years production has been maintained through the discovery of buried domes not shown by the surface topography. Improved methods of geophysical prospecting have proved to be quite successful in locating such structures, and therefore scientific subsurface study has been pushed vigorously during the past decade and the program is still vigorously under way. Various theories have been proposed to account for the presence of the well-known domes on the coastal plain; some domes are believed to have resulted from salt accumulations, while others may have resulted from igneous activities whereby crystalline masses were pushed upward into the overlying sedimentaries (see Illus. C, p. 380).

Recent exploratory work in the shallow waters offshore has indicated that similar domes exist beneath the off-shore waters of the coastal areas, and some exploratory wells have proved to be successful, thus leading to the belief in many quarters that a vast reservoir of oil extends into the strata beyond the shoreline under the waters of the Gulf. The problem of the ownership of such under-sea deposits and of the right to make contracts with oil companies for exploration and possible production has aroused much attention. Inasmuch as state sovereignty and federal sovereignty are involved, the question will probably have to be solved by action of the United States Congress and interpreted by the Supreme Court. However, companies have made contracts through state authorities, wells have been drilled under such contracts, and some production has been realized. In 1949, the problem of tidelands oil awaited attention and was unquestionably one of the major unsolved problems confronting the American oil industry. The Gulf Coast is not alone in facing the problem inasmuch as similar conditions have been found to exist off the Pacific Coast of California.

Most of the crude oil produced in the Gulf Coast Province is heavy, of asphaltic base, and not so valuable for refining purposes as are the lighter oils farther north. Some of the oil contains little natural gasoline and runs high in both carbon residue and sulphur content. Other kinds contain excellent bases for the manufacture of heavy cold-test lubricants; in such cases their value depends more upon the lubricating stock than upon the gasoline content. In recent years the improved methods of cracking heavy oils through distillation under high pressure have been important in giving value to such oils as sources of gasoline. On the whole, however, one of the chief uses for Gulf Coast petroleum is for marine fuels, and it is widely used as bunker oil for steamships.

THE ROCKY MOUNTAIN PROVINCE. The Rocky Mountain Province is a convenient geographical designation for a tremendous area which extends from the Canadian border to New Mexico (see Illus. p. 382). It includes many types of structures and topographies, and various kinds and qualities of petroleum have been discovered in the numerous pools and fields that have been explored. The most important producing states are Wyoming and Montana, but in recent years some important discoveries have increased interest in the oil possibilities in Colorado. In Utah, likewise, active prospecting is in progress with some success already reported.

In general, the oils of the Rocky Mountain Province are of the light density group, although several pools yield oils of heavy asphalt base. In view of the extensive area included in this province, its possibilities are great; however, drilling campaigns have discovered few bonanza fields so eagerly desired by promoters. During the decade of the 1930's the Rocky Mountain Province was characterized by declining production, and some students began to fear that the optimistic hopes of the earlier investigators were doomed to disappointment. However, during the 1940's expansion of exploratory work met with a high degree of success, with the result that the total production of the province doubled during the period 1940–1947. Inasmuch as exploratory work of the various possible structures may still be said to be in an early stage, the future outlook is one of considerable promise. As prices of crude become substantially higher, there is no doubt that search will be intensified, and there is a strong possibility that, in response to careful study and exploratory testing, new producing areas will be found. This, however, is a problem that must await much further exploratory work before the final verdict can be given.

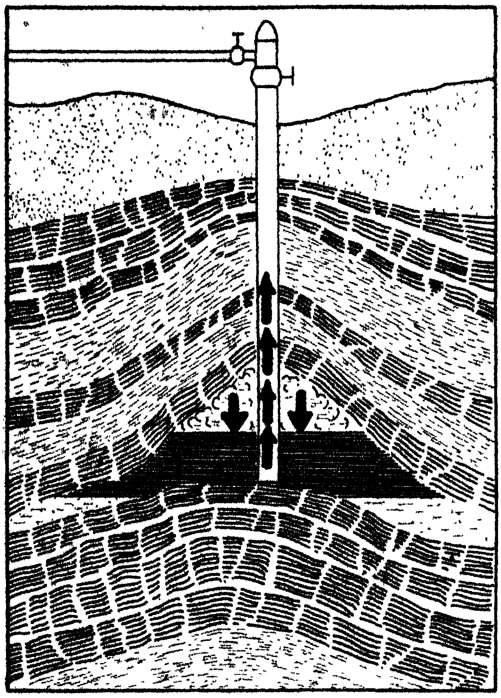
The California Province. The California Province ranks third in annual output of petroleum in the United States. It consists of two major divisions, the older one, from the viewpoint of initial development, being in the southern part of the San Joaquin Valley, and the younger in the Los Angeles area (see Illus. p. 382). Because of seepages found in various places and the presence of asphalt in rock exposures, the existence of oil in both areas was known for many years prior to exploitation. It is claimed that asphalt, the "brea" of the Spanish settlers, was mined in Ventura early in the nineteenth century and that oil refined by simple distillation was prepared from seepages near Santa Barbara as early as 1857. Wells were drilled for oil in 1884, and the first successful wells in the San Joaquin Valley were completed at McKittrick in 1887. Inasmuch as local demands were small and eastern markets were remote, development was slow until about 1900. Then, large-scale production began in the upper portion of the San Joaquin Valley, and from 1903 to 1915 California held the lead among the states in petroleum output. Since 1915 first place has been held at different times by Oklahoma, Texas, and California, but in recent years Texas has assumed a definite and probably a permanent lead.

The oil pools of California are characterized by high gas pressure, which results in heavy flush output of wells unless efficient methods of control are put to use. The quality of the oil varies from light to heavy in different pools; some is of exceptionally high quality, but, for the province as a whole, mixed and asphaltic oils predominate. In spite of low prices for such oils, the great flush production long ago made wells highly profitable and led to veritable orgies of drilling. Enormous production was obtained from several pools in the Los Angeles Basin, which in proportion to its area must be classified as one of the most productive districts in the world. Competition for the oil caused too close drilling and resulted in production so rapid that markets for a time were unable to absorb the output.

Oil interests finally became convinced that unrestricted drilling was uneconomical, not only because it entailed waste of capital expended on unnecessary wells, but also because the rapid reduction of gas pressure lessened the amount of oil which could ultimately be obtained. In recognition of this, California enacted a state conservation law to prevent the waste of natural gas and thereby not only conserved the gas for domestic and industrial use but, through maintained gas pressure, increased the amount of petroleum which could ultimately be recovered from the producing sands. Such forward-looking legislation is highly commendable because it reflects the sane view that wanton waste in utilizing natural resources is economically unsound and therefore the immediate profits of a few must give way for the greater ultimate advantage of the many.

High production of petroleum in California seems probable for a number of years, notwithstanding the tendency toward decline recently shown (see Illus. p. 384). The reserves are great, and it seems highly probable that additional producing areas will be discovered. If exploitation is kept within bounds, and wells are not allowed to run wild, the outlook is good for steady production for the years ahead. On the other hand, wherever wells are found that are capable of such large flows as are those in parts of California, there is great danger of too rapid initial production, inefficient exploitation, and consequent rapid depletion.

Origin and recovery of petroleum. The oily and gaseous hydrocarbons known as petroleum are believed to be of organic origin and to have resulted from the decomposition of ancient plants and animals. They are known to exist in the pore spaces in rocks where structures have given rise to traps in which the minute droplets have accumulated and from which escape was prevented by impervious cap-rock strata. The types of structural traps are varied; some of the ones most commonly found are shown on pages 379 and 380. Since there are no "rivers of oil," the explanation of how wells become petroleum producers, ranging from slow-yielding pumpers to spectacular gushers, must be based upon recovery from the interstices of the reservoir rock.

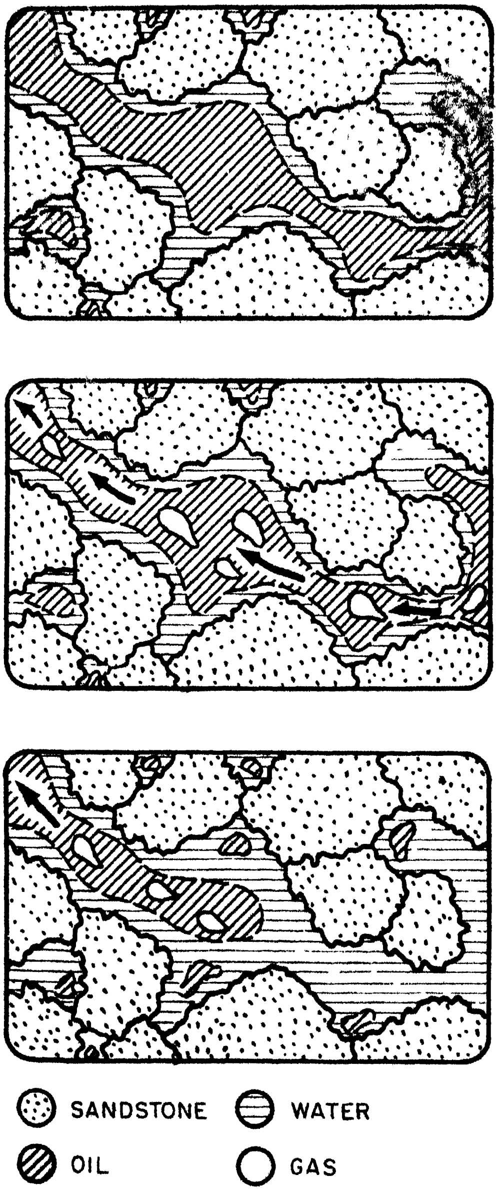


Diagrammatic illustration of how pressure of free, compressed gas in upper part of an anticline causes oil to issue as a flow well or a gusher from the underground reservoir.

The two most generally recognized sources of pressure are those of water and of gas. Oil, being lighter than water, is under pressure in some cases from water under artesian conditions; in such instances a well drilled into the oil-field rock will give rise to flowage of oil, whereas in structure farther down only water flowage would be encountered (see Illus. p. 379). The second and probably the more commonly found condition is that of gas pressure. If a well is drilled near the crest of a structure wherein free gas exists under pressure by either oil or water, naturally a "gasser" results. However, in many cases oil flowage will result apparently independent of either water or free gas pressure. Petroleum usually contains dissolved gases which remain in solution only under some pressure. In such instances a well serves to lessen pressure by providing an outlet and thus may function to release the dissolved gas at a rapid rate. When this condition is encountered, the petroleum, which may exist several thousand feet below the surface, emerges as a flowing well or even as a gusher. However, even where violent outflow is not encountered, pressure due to the release of gases out of solution will tend to move globules of oil toward the well, which by its existence provides the center of release of pressure. Wells drilled through the cap formation and the reservoir rock form a *sump,* that is, a small reservoir, out of which the oil may be pumped. It seems clear that flowage will continue as long as the oil contains dissolved gas, which by its release and resultant expansion serves as a force to induce movement of the oil through the small pore spaces of the reservoir rock (see Illus. p. 389).

The foregoing paragraph is designed to help readers to understand the reasons for the importance of maintaining strong gas pressure in oil wells as long as possible. Controlled pressure does imply that the early flush production will be held to a rate lower than could be obtained if the wells were allowed to run at full capacity, but the results will be longer life, steadier flowage, and materially increased ultimate recovery. With reckless management, more than 50 per cent of the petroleum in the underground strata may never be recovered, whereas with scientific management, whereby maximum gas pressure is maintained, ultimate recovery of more than 80 per cent of the petroleum in the reservoir rock may be expected.

Need for conservation of petroleum. Conservation of any natural resource implies its wise use, which of course carries also the thought that waste must be avoided. In so far as the petroleum industry is concerned, such waste may be the result of recklessness, selfishness, or ignorance. In any event, there is a definite loss to society, and the public good suffers. That petroleum is an *irreplaceable* natural resource

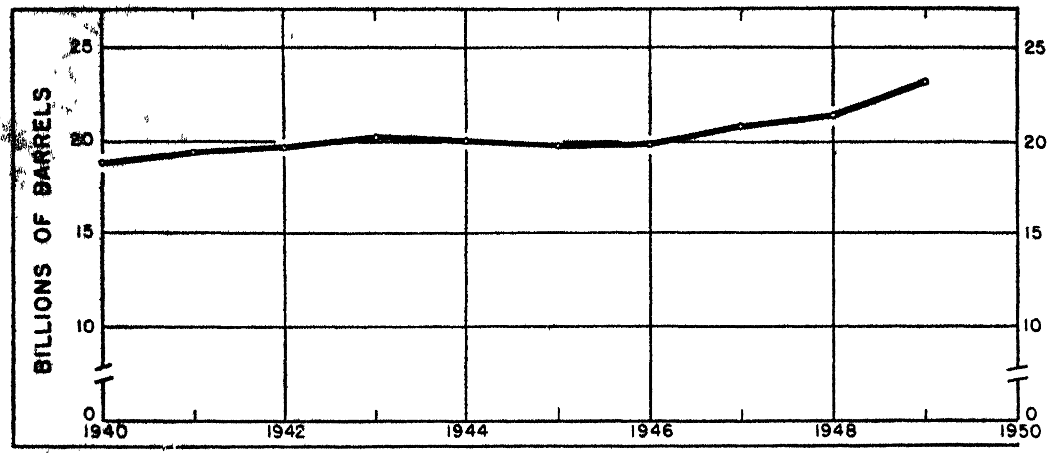


An Illustration of the Function of Contained Gas Inducing Flow of Petroleum.

Upper diagram shows oil and water in the interstices of sandstone, the reservoir rock. Liquid petroleum contains much dissolved gas which remains liquid under pressure.

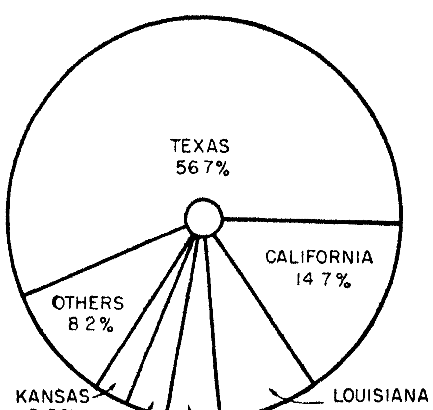
Middle diagram shows what happens when well penetrates the sandstone; reduced pressure permits release of contained gas and this moves toward point of pressure release, the well, and pushes oil with it.

Lower diagram, after well has been producing for a long period, gas pressure nearly gone. The well then becomes a slow producer.



(A.) Estimates of proved reserves in the United States annually since 1940. Their rising curve is evidence that discoveries made by wildcat and development drilling have exceeded the heavy production of these years.

should always be kept in mind. The petroleum produced each year means that just so much less remains to be withdrawn. While it is statistically true that, in spite of heavy withdrawals during the war and postwar periods, the proved resources of petroleum had reached an all-time high early in 1949 (see Illus. above), that does not imply that the actual reserves had increased; on the contrary, the actual reserves of this country were higher when Drake struck oil in 1859 than they have ever been since. Through exploratory drilling and improved techniques in production, knowledge concerning stores of petroleum available underground has increased, and thus estimates have expanded faster than production. As a result, the quantity of *proved reserves* still available has increased, although the actual reserves are becoming less with each passing day.



(B.) Percentage of proved reserves of petroleum in the United States credited to each of the principal producing states as of January 1948.

What, then, is the duty that confronts every intelligent citizen? It is, first of all, to recognize that petroleum prepared by Nature is a priceless resource, indispensable in the modern world in times of peace and war alike. Improved techniques of production will make higher ultimate recovery possible, but even so, every pool, field, or province will eventually suffer decline and final exhaustion. Waste in any form hastens the day. The most serious form of waste now recognized is that of allowing gas to escape without being put to any use. This practice has been tolerated in the oil fields for an inexcusably long time, and even now such waste is all too prevalent in some fields. Fortunately, however, the importance of gas pressure as a factor in oil production is becoming more fully understood, and consequently, control measures are becoming incorporated into the conservation laws of oil-producing states. Other phases of conservation in which all citizens should take interest include such matters as maintaining internal combustion engines at high standards of efficiency and avoiding loss of leakage or evaporation in tanks or in transportation.

Transportation and storage. When production of petroleum in large quantities began, the producers were immediately confronted with the problem of its transportation. Petroleum was then a new type of commodity: the railroads were not equipped for the efficient handling of liquid freight. Haulage at first was in barrels, a method that proved inadequate from the outset. This led to mounting tanks on railroad trucks, and thus was initiated tank-car shipment of crude to refineries.

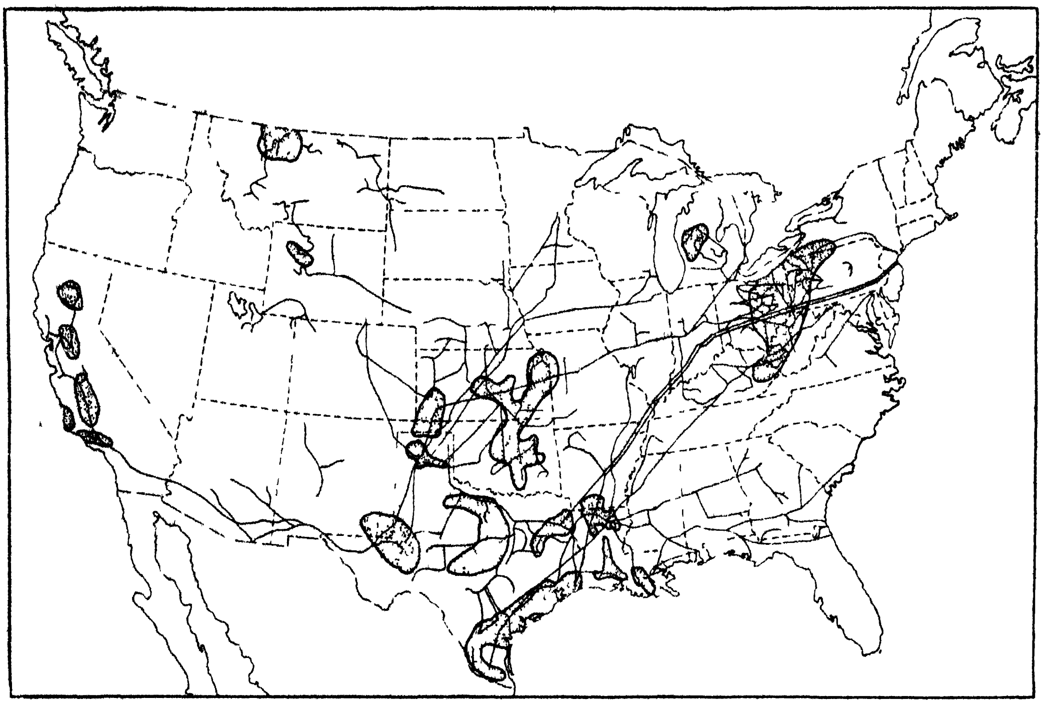
The flush production of some of the pools so greatly exceeded even the most hopeful expectations that tank cars with which to handle it were not available. In short, the freight-car type of transportation for crude oil was not flexible enough for the oil industry, a fact which became obvious within a few years after the discovery well at Titusville had been brought into production. Nevertheless, tank-car shipments by rail have continued to be of importance in the oil industry throughout its history. On the basis of carload lots alone, petroleum and petroleum products now constitute 4 to 5 per cent of the total carload freight hauled by American railways. In 1947 there were over 159,000 railroad tank cars in the petroleum service.

Pipe lines. Transportation of crude oil through pipe lines was an outgrowth of the method used successfully by water systems. This method of moving oil was first used in Pennsylvania about 1865, where the practice began with wooden pipes, which were soon replaced by pipes of iron and steel. This method of transportation has grown to such magnitude that many sections of the United States are served by a veritable network of pipe lines (see map, page 382). This is the most efficient and least costly form of overland freight haulage that has yet been devised. The total mileage of pipe lines for transporting petroleum, refined products, and natural gas is reported to have reached the astounding figure of more than 400,000 miles. The term "pipe line" now implies a complete transportation system, including trunk lines, gathering lines initial and terminal storage systems, commercial lines, and power plants.

Steel pipes of twelve to twenty-six inches in diameter are used for most of the trunk lines, while those of smaller diameters are used for the gathering lines and some of the main lines. The oil is moved by means of pumping stations which serve as boosters or pushers to force the petroleum from one station to the next. These power pumping stations are spaced from twelve to over fifty miles apart according to the density of the oil, topography, and climatic conditions.

Because of its cheapness and its flexibility of operation, the significance of pipe-line transportation can hardly be overstated. The pipe-line movement of crude oil in recent years has reached the astonishing total of more than 1,400,000,000 barrels per year. Until recent years, petroleum pipe lines were used only for transportation of crude oil; but with enormous increases in demands for gasoline in cities located far from the oil fields, and with growing competition in marketing oil products, the industry was compelled to seek the cheapest possible methods for the distribution of gasoline. Pipe-line transportation was the answer. The first important shift in this direction was the conversion of a large pipe line running from western Pennsylvania to the Atlantic seaboard. Formerly it carried crude from the oil fields of the west to the refineries of the east. Now it carries gasoline from the east to the markets west of the Alleghenies. The most striking example of moving gasoline on an immense scale by pipe line was that of the well-known "Big Inch" line, which carried gasoline from the fields of Texas and Louisiana to seaboard outlets of the Middle Atlantic Coast. While the "Big Inch" was a wartime expedient, it served its purpose well during the emergency, and it was later converted to a means for distributing natural gas from the same states to the markets in the great population centers of New York and Pennsylvania. (See map, below.)

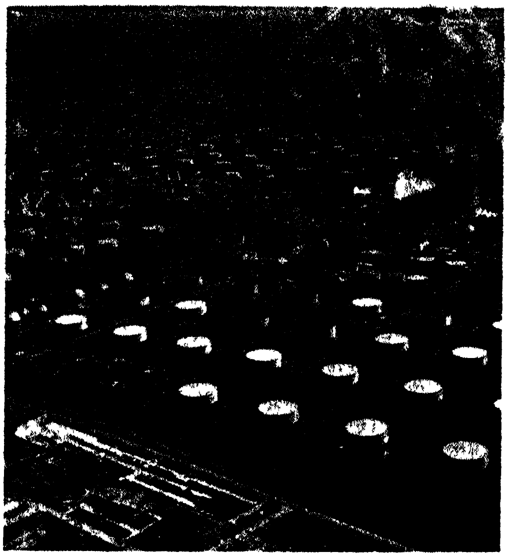
Recent years have witnessed an enormous extension of pipe lines for the distribution of natural gas. Main lines now connect the gas fields of Louisiana, Texas, and Oklahoma with such distant cities as Minneapolis, Chicago, Detroit, and New York, and extend westward to Los Angeles. Some of the main lines are of huge diameters, from eighteen to thirty inches. To lay these lines over hill and dale and across large rivers and to construct them leakproof is a job of the first magnitude, but problems of manufacture and construction have been so successfully met that this form of transportation has been expanding with phenomenal rapidity. The total mileage of pipe line for crude oil and products transportation increased from 195,000 miles in 1940 to about 250,000 miles in 1948, with the upward trend still evident.



Map of major fields of natural gas and of principal gas pipelines in the United States as of September 1947. Note general similarity to petroleum map on page 382.

Tank farms. Oil from producing wells is run through pipes into receptacles known as producers' tanks. These tanks may be large or small, varying with the type of production. Where strong wells occur, the producers' tanks are large; where small wells prevail, the tanks may hold not more than two hundred to five hundred barrels. From these the oil is transferred by gravity or by pumping into the working tanks which belong to the pipe-line systems, and which vary in capacity from 5,000 to 90,000 barrels each.

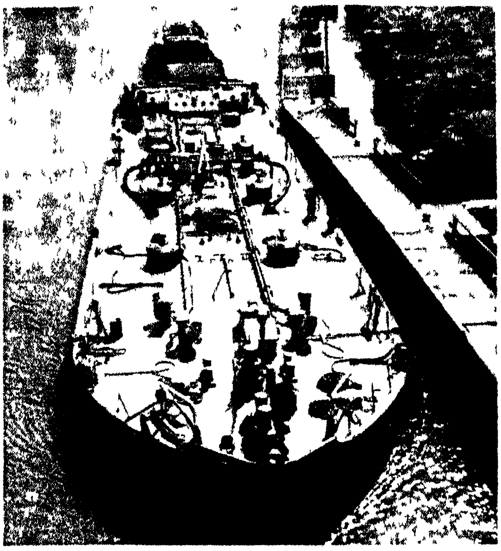
Tank farms are aggregates of storage tanks built in connection with the large refining and shipping centers. They consist of tanks into which the crude is received from field production and serve as the supply for refinery operation. They are large establishments, some of them providing storage for more than 10,000,000 barrels of petroleum. Aside from carrying a sufficient amount of oil above ground to assure steady operation of refineries, nothing is gained by the use of tank farms because underground storage is the best and cheapest method. Substantial increase in total tank storage capacity in the United States therefore seems unnecessary as long as petroleum is the principal fuel involved.


Courtesy Standard Oil Company, New Jersey

(A) Tank farm and Baton Rouge refinery from the air, January 1948. Note extensiveness of plant and different shapes of tanks. Why are earthern embankments prepared around each tank?

OIL TANKERS. When shipment of crude oil by water became necessary, a new type of vessel, the tanker, was devised to meet the demand. It is a steel ship divided into compartments and equipped with pumping apparatus whereby loading and unloading may be quickly accomplished. With the development of extensive international trade in petroleum, tanker tonnage has had almost phenomenal growth. See Illus. B above.

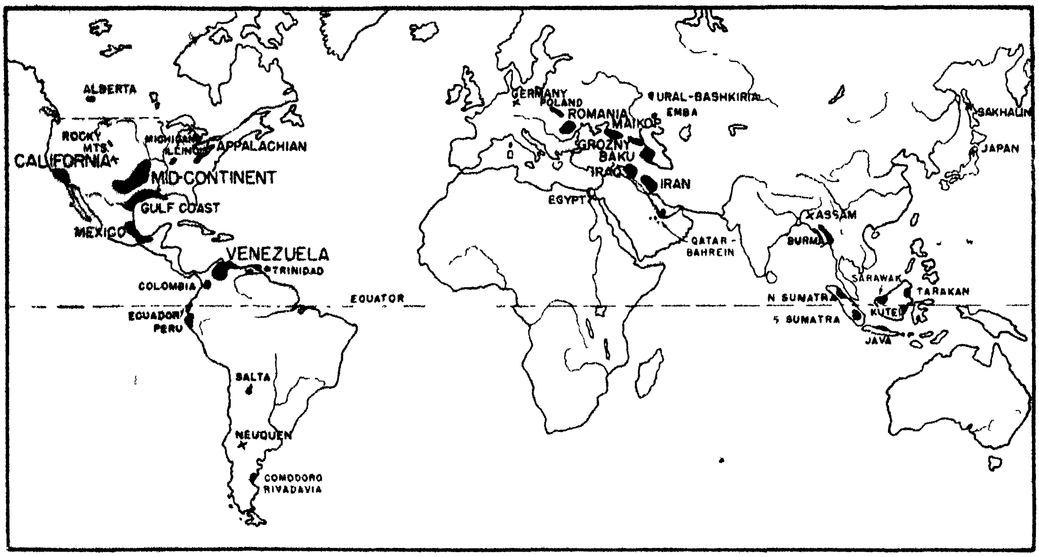
Tankers plying between Caribbean ports and New York City have capacities of 80,000 to 150,000 barrels of crude. In general, smaller boats ply between Mississippi and the Gulf of the United States, whereas much larger ones operate in the trans-Atlantic service, some recently constructed being reported capable of carrying 228,000 to 240,000 barrels. The sturdiness and efficiency of these ships make the importation of petroleum from the Middle East to American refineries economically practical in competition with domestic production. Of even greater significance is the assurance they give of adequate, dependable supplies from South America and from overseas sources to supplement the domestic production as need may develop.


Courtesy Standard Oil Company, New Jersey.

(B) Oil tanker entering a lock in the New York State Barge Canal. Petroleum and petroleum products are the principal freight handled by the canal

Petroleum in Foreign Countries

Since 1859 the United States has produced approximately 65 per cent of the total world supply of petroleum; at the present time about 60 per cent is being produced in this country. The foreign countries which rank high in importance are the Soviet Union, Venezuela, Persia, Iraq, Saudi Arabia, Indonesia, Romania, and Mexico (see Illus. p. 394). The probable reserves of oil and gas of the various continents are far from equal. On the basis of present evidence, North America must be rated highest and the United States given the most favorable position among the nations. However, present estimates indicate that the reserves of the Eastern Hemisphere, now considered to be proved, exceed those of the Western Hemisphere (see Illus. below).



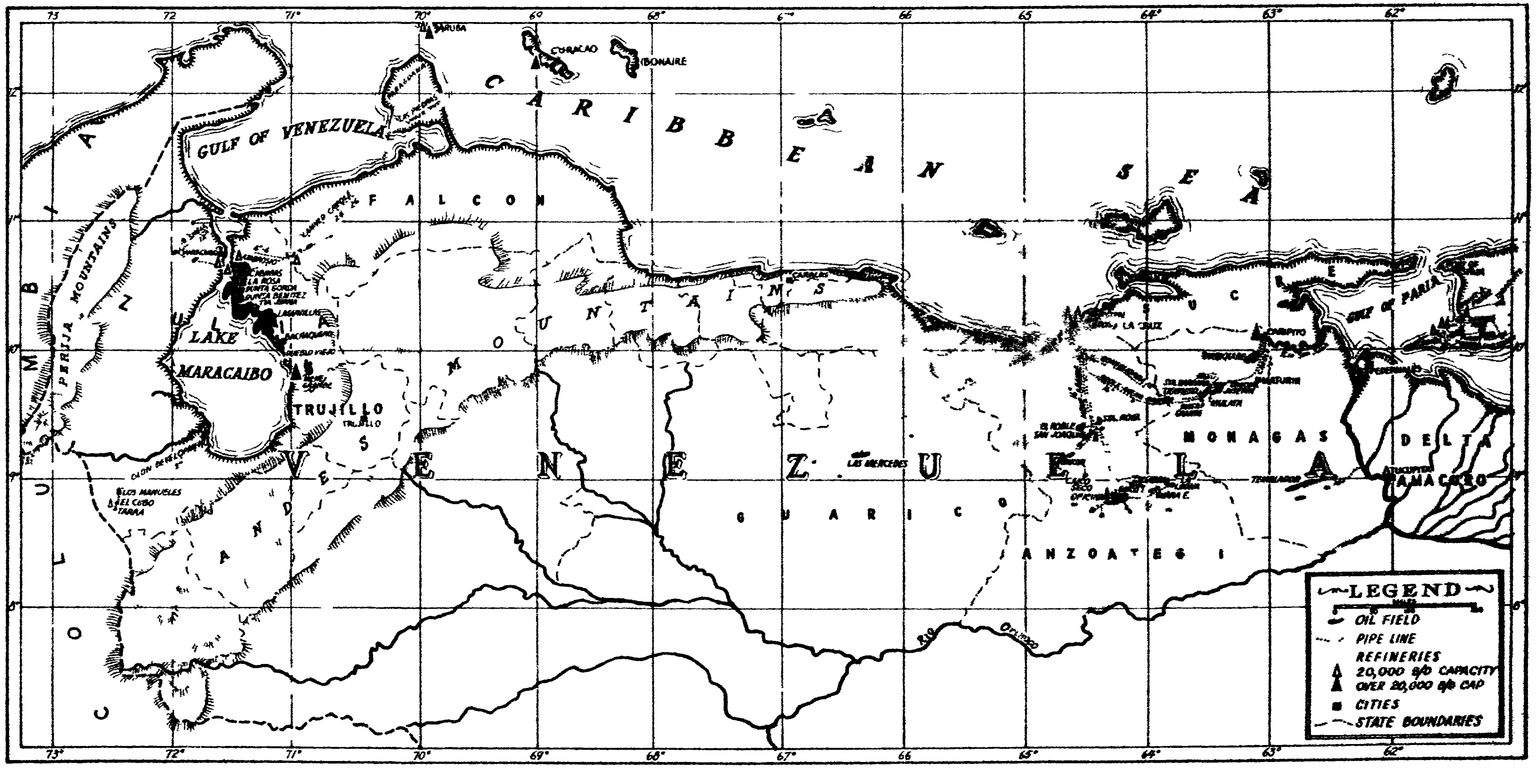
World map of principal petroleum producing areas

In the Western Hemisphere the vast plains which begin in Canada, extend through the United States, and terminate in eastern Mexico comprise the most promising and at the same time the most productive large area as yet known in the world. However, the potentialities of South America have not been completely explored, and therefore knowledge concerning possibilities there is definitely incomplete. A similar statement would apply to the oil reserves of the Near East, from the Mediterranean Sea to India and embracing the vast area which includes Arabia, Iraq, and Persia.

South America. In South America the best undeveloped prospects appear to be in the valleys of the Orinoco and the Upper Amazon and in the plains east of the Andes from Argentina to Colombia. Most of eastern Brazil is a crystalline upland where the existence of oil over any large areas is not believed probable. The vast stretches of the Andes are so severely distorted that within the mountain area oil can occur only in scattered basins.

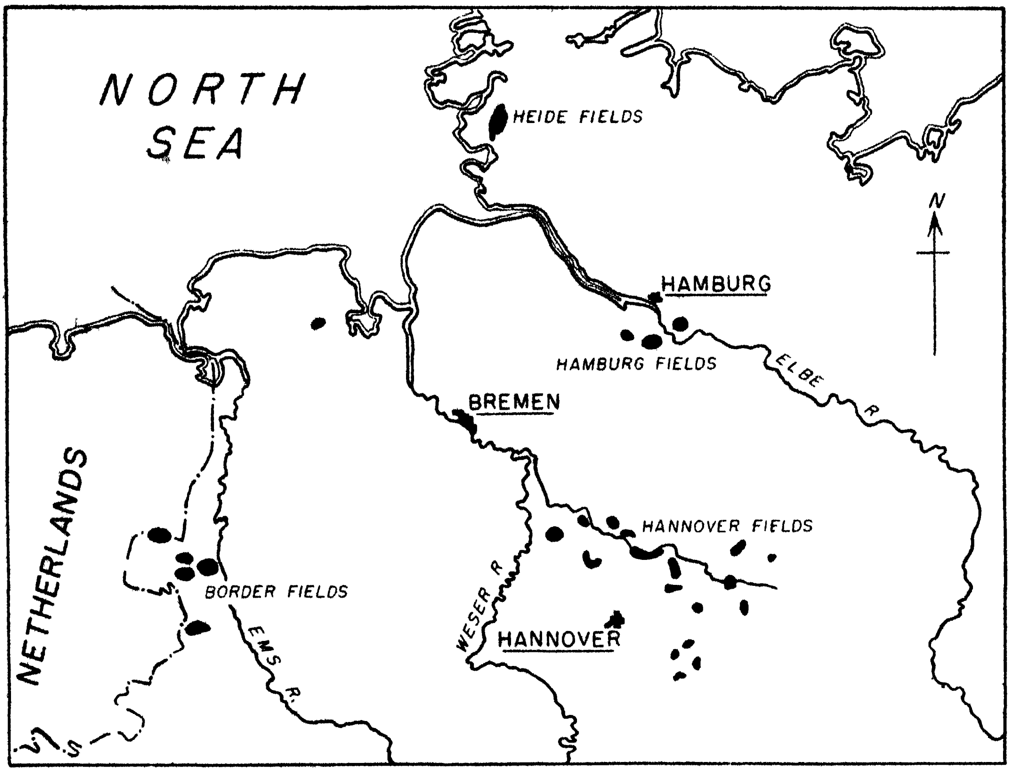
Commercial exploitation has thus far proved successful in Venezuela, Colombia, Ecuador, Peru, and Argentina. The first-named has ranked second or third in world production for a number of years, with the Maracaibo Basin as the chief center of operations. Commercial production has now been reached in the Orinoco Basin, and there seems to be a strong probability that large reserves exist there (see map, page 395). For the entire country the annual output has reached nearly 400 million barrels and the rising trend promises to continue for some time. Venezuela may therefore be expected to retain her position as one of the leading petroleum countries of the world.

Peru first appeared in the records as an oil producer in 1896 but did not reach the million barrel per year figure until 1909. Since 1935 the annual production has



Map of Venezuelan Oil Fields, 1948 Reprinted by permission of the *Oil and Gas Journal,* Tulsa, Oklahoma ranged from 12 to 15 million barrels. The fields are in the northwestern part of the country along the Pacific Coast, south of the Gulf of Guayaquil. Exploratory work is going on in Peru east of the Andes with prospects of success apparently favorable.

Production in southwestern Ecuador has continued moderately successful for many years; output there first exceeded a million barrels in 1928 and since then has remained comparatively steady at from two to three million barrels per year. In Ecuador, as in her neighboring nations, exploratory work is going on east of the Andes, with results as yet undetermined.



Map of principal oil fields of Germany. The Wietze field, discovered in 1874, marked the beginning of commercial production Domestic production has never exceeded 25 per cent of requirements.

In Colombia the principal producing fields are on the low western flanks of the Andes, about 425 miles inland east of the Magdalena River, and in a more recent development on the eastern flanks of the mountains in valleys that drain into Lake Maracaibo. This production is piped across the Andes, where it meets but does not join with production from the earlier fields for export through the Magdalena Valley to overseas markets. Since 1940 the output of petroleum in Colombia has ranged from 12 to 23 million barrels per year, but the possible production appears to be much greater than that actually attained. The oil fields are connected with ocean shipping facilities by pipe lines more than 400 miles long.

Argentina has had slow but steady growth in petroleum output since 1913. The annual production in late years has ranged from 22 to 27 million barrels with prospects of further increase during the years ahead. The principal centers of output are the Comodoro Rivadavia field, about 900 miles south of Buenos Aires, and the more recently discovered fields east of the Andes in central and northern Argentina (see Illus. p. 382). These fields appear to continue northward into Bolivia, and perhaps even farther north, with extensions still to be determined. In Bolivia, active exploitation is under way, induced by American interests which are willing, because oil seeps have long been known, to risk money for development despite considerable uncertainty as to safety of investments due to unstable political conditions.

Chile has been the scene of considerable exploration for a number of years, but results were negative until production was discovered in 1945 in Tierra del Fuego. Reports indicate probability of successful exploitation in that southernmost part of South America, with the possibility that the producing area may extend into the eastern part of the island, which is Argentinian territory.

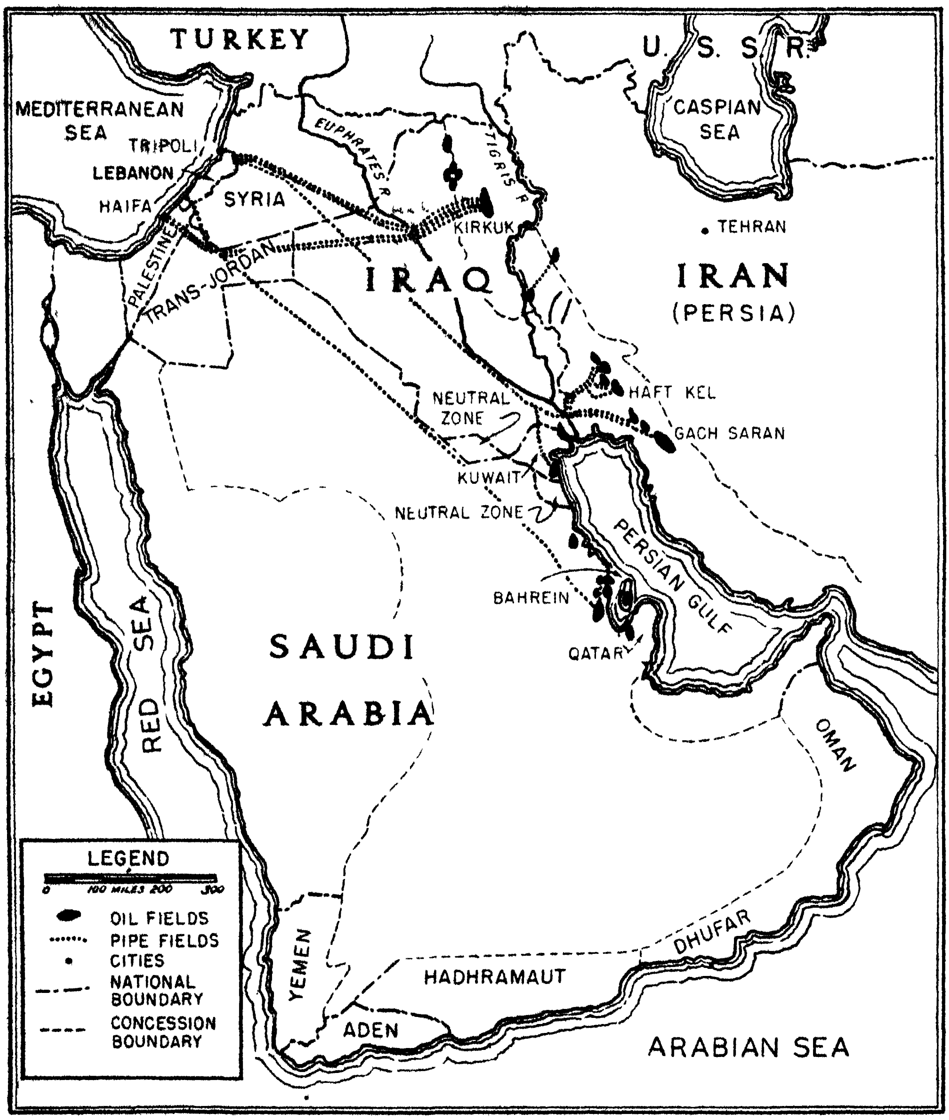
Europe. The rock structures of southern and western Europe are so broken and disturbed that it does not seem probable that any extensive petroliferous areas will be discovered. Small fields are well known and they are located in such widely scattered places as Alsace, Hanover, Galicia, and Romania. Recent developments have given further impetus toward hope of substantial output of petroleum in northwestern Germany and adjacent parts of Holland (see map, p. 396). In eastern Europe, in addition to the important Caucasus area, Russia is characterized by extensive plains with structures similar to those which have yielded much oil in interior United States. Therefore, these Russian plains, at present of little importance in the oil industry, appear to have potentialities which may become revealed through further exploration.

Romania and the Soviet Union. Romania and the Soviet Union lead all other European countries in output by a wide margin. Romania has been producing petroleum for more than eighty years; during most of that time the production was comparatively small. However, the output gradually increased, reaching 40 million barrels in 1929 and over 60 million barrels in 1936, since which time there has been a rather persistent decline to 30 or 35 million barrels yearly, with the declining trend still in evidence.

Russia became a petroleum producer before 1870 and has consistently been one of the leading nations, usually ranking second, although in late years her position has probably dropped to third place because of the rapid development in Venezuela. For several years in the early part of the present century, Russia ranked first, surpassing even the United States. The principal fields are in the southeast and near the Urals; the Baku field on the Apsheron Peninsula and the several fields along the north flank of the Caucasus Mountains are especially important (see page 382). The production of petroleum reported in 1944 reached 275 million barrels, since which time specific data have not been available. In all probability, production in the Soviet Union is increasing and may be expected to continue to do so for some years to come. The vast plains and intermountain basins which characterize the topography suggest structures which may become producers as exploratory work proceeds. It appears probable, therefore, that the Soviet Union will continue to rank as one of the three or four largest producers of petroleum among the nations of the world.

Asia. From the petroleum standpoint, the extensive continent of Asia, including Siberia, is largely an unknown area. The results of exploratory work so far carried on have not been publicized to any large degree, and therefore the meager information at hand is fragmentary. The most promising areas appear to be in western Siberia, in the plains and foothill belts east of the Caspian Sea, in southwestern Persia, in Iraq, and in the Lowlands bordering the Persian Gulf in Arabia. Such exploratory work as has been completed has been rewarded with extraordinary success.

Persia. In American statistics, Persia first appeared as an oil producer in 1913, credited with an output of 1,857,000 barrels. At first, progress was slow, but since 1920 it has been rapid, leading to an output of approximately 324 million barrels in 1948 and placing the country fourth among the nations in petroleum production (see Illus. below). The producing areas are along the south flank of the Bakhtiari Mountains of western Iran, north of the head of the Persian Gulf. The crude is transported by pipe line to large refineries constructed on the island of Abadan, below Basra, whence the products are shipped by water routes to the export markets of Asia and Europe. English and American interests have provided the major share of the capital necessary for the development of the Persian oil industry. Inasmuch as vigorous explora-



Map of petroleum production of countries east of the Mediterranean Sea. The oil fields shown rank among the richest in the world.

tory and drilling campaigns are continuing, the future promises still greater production.

Iraq. The kingdom of Iraq is another of the later additions to the family of petroleum-producing nations. The oil fields are located near Kirkuk in northern Iraq about one hundred miles southeast of ancient Nineveh (see page 398). Although strong wells were struck a number of years ago, commercial production was delayed because of lack of transportation facilities. A 1,150-mile pipe line of 12-inch diameter with a daily capacity of 85,000 barrels was begun in 1932 and completed for active service in 1935. It is a double line from Kirkuk to Haditha on the Euphrates, a distance of 150 miles, where it bifurcates, one line crossing Syria to Tripoli on the Mediterranean coast, the other crossing Transjordan and Palestine to Haifa. More recently a parallel line of equal diameter has been constructed and placed in operation, thus doubling the carrying capacity of the original line. It takes crude from Kirkuk about twenty-one days to reach Tripoli and twenty-five days to reach Haifa. With production holding fairly steady, present indications point to Iraq's continued prominence as a petroleum-producing country.

Arabia. In recent years American interests have undertaken extensive exploratory investigations in the vast territory commonly designated as Arabia (see page 398). This territory includes among others the several governmental units known as Transjordan, Saudi Arabia, Kuwait, the Bahrein Islands, and several others. Strong wells have been discovered and some are in active production. To date, the principal difficulty has been that of transportation, but present plans call for pipe lines of large diameter to be extended across the desert to the shores of the Mediterranean. The Bahrein Islands and Saudi Arabia have already become well recognized as rating among the great producers of the world, Saudi Arabia being credited with 135,000,000 barrels of petroleum production in 1948. Recent agreements reached by American and British interests have given to both countries important stakes in the production of the several countries of the Near East, but American capital seems to be carrying the greater financial investment and the greater responsibility in the development of production and marketing. If present indications are borne out by further tests, this part of the world as an entity may rival the great petroleum-producing areas of the New World. Present prospects, at least, indicate that the Near East will probably be the reservoir from which the needs of the Eastern Hemisphere (particularly Western Europe) will largely be met. [illegible]

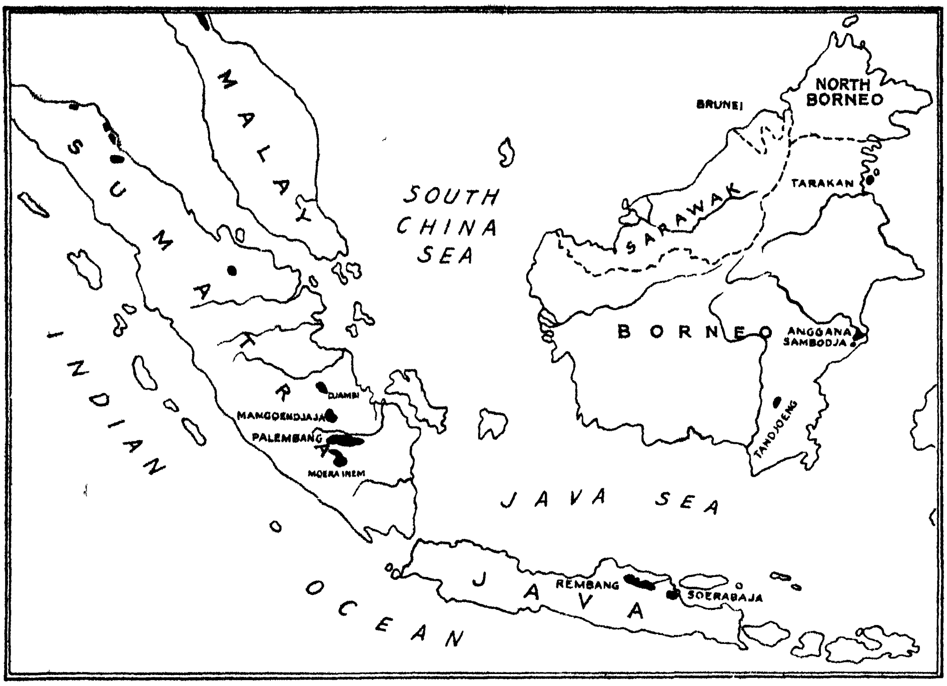
Southeastern Asia. India and the East Indies have long been important in the petroleum industry of the world (see Illus. p. 400). India's production dates back to 1894. Increase was slow but steady until 1915, when the output had increased to 8 or 9 million barrels per year, after which decline set in so that in recent years the output has been less than 3 million barrels.

Sarawak (British Borneo) has been comparatively prominent as a petroleum producer since 1920, the output exceeding 6 million barrels in 1946; however, the output of recent years indicates that the trend has apparently been stabilized at about 5 to 6 million barrels per year with the possibility of gradual decline setting in. English interests are dominant in both India and Sarawak.

The Netherlands Indies became an important oil producer in the nineties and has remained so during the intervening period. The output in 1939 was approximately 60 million barrels, but in later years the production was less, probably because of the effects of war and the postwar disruption. In 1946 recovery had set in and 40 million barrels were produced. Whether the upward trend will continue, only the future can answer. The capital interests are chiefly but not exclusively Dutch.

Eastern Asia. Japan, including the island of Taiwan (Formosa), has appeared in the list of petroleum-producing countries since 1875, but the output was small until after the turn of the century. In spite of energetic exploratory work, the annual production remained at a low figure, exceeding slightly 3 million barrels during the prewar period. Since then, production has been reduced to 1.5 million, and at present there is no indication that any material increase may be expected (see Illus. p. 382).

Manchuria, Korea, and Eastern Siberia, including the coastal islands, include areas which are classified as potential petroleum producers, but actual output to date has been small. Some have given China a high rating in petroleum potentialities, but the published evidence is not reassuring.



Map of principal petroleum fields in the East Indies. Reprinted by permission of the *Oil and Gas Journal*, Tulsa, Oklahoma.

Africa. Egypt is the only country of Africa where important petroleum production has been achieved. The first commercial production was reported in 1911, and for some years the prospects for large output were widely heralded. These have not been realized, however, and the yearly output has reached only about 9 million barrels. Although wells in some other countries of Africa have proved the presence of oil, economic returns in general have been disappointing. Africa is not credited with any large oil potentialities. Much of the interior of the continent is a crystalline plateau with slight likelihood that oil may be found. Most of the Sahara is unknown territory as to oil possibilities. The small quantities thus far produced in Africa have been obtained from the folded sedimentaries which in some localities fringe the margins of the continent, and further discoveries will probably be limited to the same types of areas.

Australia. Australia likewise has areas of crystalline rocks too extensive to warrant hope of any large percentage of potential oil land. Local pools may be found, but as a continent it does not appear likely to attain high rank.

Capital interests. On the basis of present knowledge, the great oil reserves of the world are in North and South America, in the Soviet Union, and in the Near East countries of southwestern Asia. The capital interests of the United States, England, the Netherlands, and the U. S. S. R. control the major portions of the world's future oil reserves in so far as they can now be estimated. The economic and political control of the world's reserves is not easy to determine with exactness, but it seems safe to say that outside of the Soviet Union the oil industry is largely in the hands of British and American capital.

When coal was the bunker fuel of the day the British developed coaling stations all over the world in order to give fuel service to ships in merchant commerce. With the shift to petroleum, she was in position to equip similar stations for bunkering with petroleum and its products, a situation of which she took full advantage. With the ascendancy of petroleum and the greater flexibility that its use involves, the Americans, however, became active rivals with Britain in providing the fuel and power resources for maritime trade. The present outlook is that this condition will continue and that no one country will be in a position of virtual monopoly.

Summary of the petroleum outlook. The expanding use of liquid fuels promises tremendous consequences in industrial development. Through new technological processes, it is possible to convert practically all the crude petroleum into valuable products and by-products. Petroleum has become one of the great raw materials for the ever-expanding chemical industries. This means increased efficiency to a degree that few believed possible some years ago. Furthermore, experiments are in progress for the purpose of determining the practicality of liquefying coal and also of converting coal into gas at the mines. If these experiments should indicate probability of commercial success and thus lead to the establishment of plants for conversion of coal into a liquid or gaseous fuel at the mine, the effects upon transportation and industry would be revolutionary. Haulage of liquids or gaseous fuels can best be accomplished by pipe lines. Until recently, only crude oils were so transported, but now pipe lines are also used for transporting the light derivatives—especially gasoline. Should the experiments now in progress for liquefaction of coal become commercially successful, and should the products be transported by pipe lines, the railroads would be deprived of the revenue provided by the greatest single commodity now being carried. The effects of such change would extend to practically every realm of industry, affecting the manufacture of rolling stock, the steel output, and a host of industries contingent upon coal and steel as key commodities.

The petroleum industry of the world thus far has been built largely upon the basis of American production. This can readily be understood if we bear in mind that the United States has provided nearly two-thirds of all the petroleum used in the world since 1860. Even with that tremendous drain upon the original store of resources, the proved quantity of petroleum still in reserve is greater than it has ever been known to be before. Now, however, scientific evidence indicates that the unmined reserves of the Eastern Hemisphere may exceed the unmined reserves of the Western Hemisphere and that in the future, perhaps the not distant future, the United States will be in the position of a buyer of petroleum and petroleum products rather than a seller. England early realized the necessity of depending upon sources of petroleum beyond her own borders, and thus, almost at the outset of the modern petroleum age, she became powerful in the international field of operations. More recently capital interests of the United States have become aware of the dangers of too great dependence upon domestic reserves already heavily drawn upon and, therefore, have undertaken extensive exploratory and developmental programs in foreign countries, particularly in South America and in the Near East. The necessity of maintaining a strong position in the realm of petroleum carries with it international obligations and the formation of international policies of the highest importance. It appears probable, therefore, that in the years ahead American and British interests facing common needs and common problems will, as a matter of economic as well as political expediency, be found working as a team.

Within the United States the great change needed is that of conservation. The efficiency of the industrial methods used is high and undoubtedly will remain high. Production methods, however, have in too many cases been negligent in conserving gas pressure in order that maximun production might be realized. Wells have been drilled too close together. Spacing has not been carefully studied and unit operations have in most cases been avoided. A hopeful aspect, however, is that the petroleum industry is becoming aroused to the necessity of careful planning and execution of scientific methods of exploitation. The only way in which efficient methods of conserving this irreplaceable resource can be carried on must be based upon co-operation and not upon uncontrolled individual competition. With the application of scientific methods and the adoption of sane administrative procedures, the petroleum industry will be in a position to meet our individual and national needs for the foreseeable future. To do this, however, the industry must continue to be dynamic in its attitude toward new conditions and new problems as they develop.

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Chapter Twenty-three

WATER-POWER RESOURCES—THEIR DISTRIBUTION AND INDUSTRIAL SIGNIFICANCE

ORDINARILY WE ADMIRE THE CLOUDS because of their ever-changing forms or because they remind us of sailboats carried to their destinations by strong and steady winds. We should admire them as evidence of one of the most essential transportation agencies known to man. Clouds consist of minute globules of moisture condensed out of the invisible water vapor always present in the air. Thus, quantities of moisture, as vapor and as clouds, are transported thousands of miles to be unloaded as rain, snow, or hail wherever conditions are favorable for precipitation.

Of the moisture that falls on the land, much evaporates or soaks into the ground; but estimates made on the basis of extensive field studies indicate that 30 to 35 per cent of the rainfall becomes run-off water in brooks, creeks, and rivers. This is the water, some of which is impounded into lakes at various altitudes, that makes water power possible. The total potential water power of the world is estimated to be at least 664 million horsepower, of which only 13 per cent had been developed by the close of 1947.

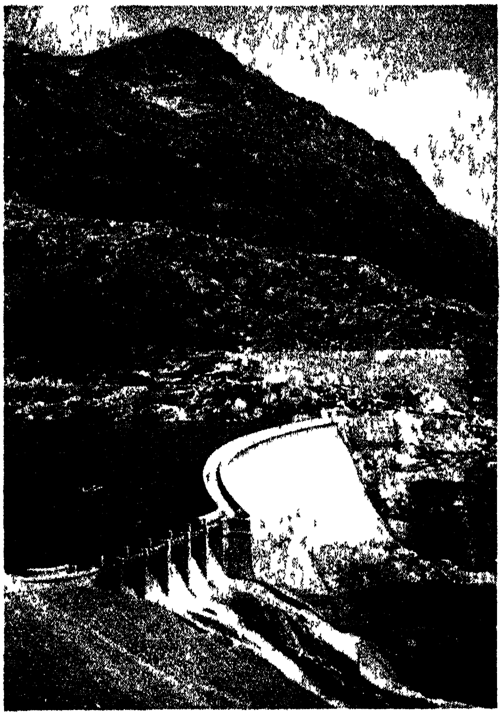
Streams as early sources of power. Streams have long been utilized as sources of power because man learned to make a simple paddle wheel for the water to turn to do work (see Illus. A, p. 404). By such primitive methods only small amounts of water power could be developed. In order to render the flow more uniform and dependable, it was necessary to construct reservoirs, but these could not be large because the means of constructing strong, nonleaking dams had not been discovered. No wonder that with the advent of the steam engine man turned to coal as a larger and more elastic source of energy than running water.

The mechanics of development of water power. Three major inventions have provided the magic whereby water power has been changed from a Cinderella to a princess. The invention of the *turbine* made it possible to use much larger volumes of water and to increase greatly the height and therefore the pressure of the confined water column upon the blades. The invention of the *dynamo* made it possible to convert the energy of the falling water into electricity. The invention of *Portland cement* enabled man to construct dams hundreds of feet high and thousands of feet long by means of which even the largest rivers can be impounded safely. As a result of such inventions, hydroelectric power has, within the past fifty years, attained a status of major importance in most industrial countries (see Illus. B, below).

The amount of energy in flowing water depends upon the quantity of water and the velocity of the current. The latter, in turn, depends upon the gradient of the stream. The Mississippi in its lower course has a gentle gradient, its waters are sluggish, and the river does not offer attractive possibilities for power development as does, for example, the rushing, turbulent Columbia with its relatively steep gradient. Waterfalls and rapids represent the maximum velocity of flowage and usually make the best water-power sites. However, in order to harness the energy of a stream and thus convert it into power, it is necessary to stabilize the pressure of water upon the blades of the turbine. This is accomplished by building a dam, in some cases hundreds of feet high, to serve as a reservoir, thus making a dependable quantity of water available regardless of seasonal rainfall fluctuations. From the foot of the dam the water is led through a *penstock* to the turbine, where pressure against the blades causes revolutions which are transmitted to the dynamos for the generation of electrical power. Penstocks, whether vertical or inclined, are always much larger at the intake than at the outlet and are so constructed that any disturbances of the surface waters of the lake or reservoir above the dam will not affect the pressure of the water at the outlet to the turbine. This is of course necessary in order to insure steady generation of current by the dynamos. The pressure per square inch on the blades of the turbine is 0.433 pounds per foot of vertical distance from the surface of the water to the point where the water enters the turbine through the penstock.

Photo by N A B

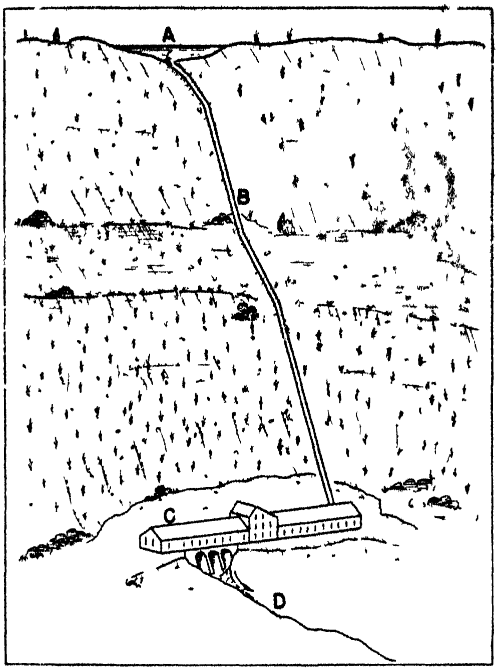
(A) Old waterpower mill in Massachusetts, restored by Henry Ford Mills of similar type provided most of the mechanical power utilized by grist mills and saw mills until after 1815.



Courtesy Legation of Switzerland, Washington, D C

(B) The Barberine Reservoir of the Swiss Federal Railways near Chatelard in the Valais Power is developed by the water pressure back of the dam The power house, not shown, is along the canyon wall below the dam.

Where power is generated at waterfalls, the water is taken out some distance above the falls and led by canal through a rock tunnel and thence through a penstock to the power house near the bottom of the gorge below the falls, where the pressure is released at the narrow outlet against the blades of the turbine which in turn drives the dynamos (see Illus. A, below). The electric power thus generated is carried by copper wire to be distributed through stations to places and plants where needed. At Niagara Falls, where power has been developed in this way, the power companies have constructed long intake canals and rock tunnels to carry the water to the penstocks. Unfortunately, diversion of water sometimes impairs the beauty of the falls. In most cases, however, as at Niagara, a happy medium can be struck, satisfying both the requirements for power and the demands for the preservation of natural beauty.



Sketch by Glenn Downey, Univ of Nebraska

(A) Pen sketch of penstocks (B) connecting the Barberine Reservoir (A) with the turbines and generators in the power house (C.) The water pressure is measured by the height of intake at A above the turbines in the power house Water escapes below the power plant and forms the stream.

In mountain areas of the Alpine type the streams derive a fairly steady flow from the permanent snow and icefields of the summit regions. These snow fields have often been referred to figuratively as "white coal"—a term now widely used for hydroelectric energy. Most mountain streams are relatively small, but their gradients are so steep that without much difficulty man can impound reservoirs and utilize the pressure obtained by the great drop from the heights to compensate for the smaller amount of water available. In the Alps and similar high mountain areas are some sites where the water descends from four to five thousand feet through penstocks before reaching the turbines at the base (see Illus. at left).

Courtesy Legation of Switzerland, Washington, D C

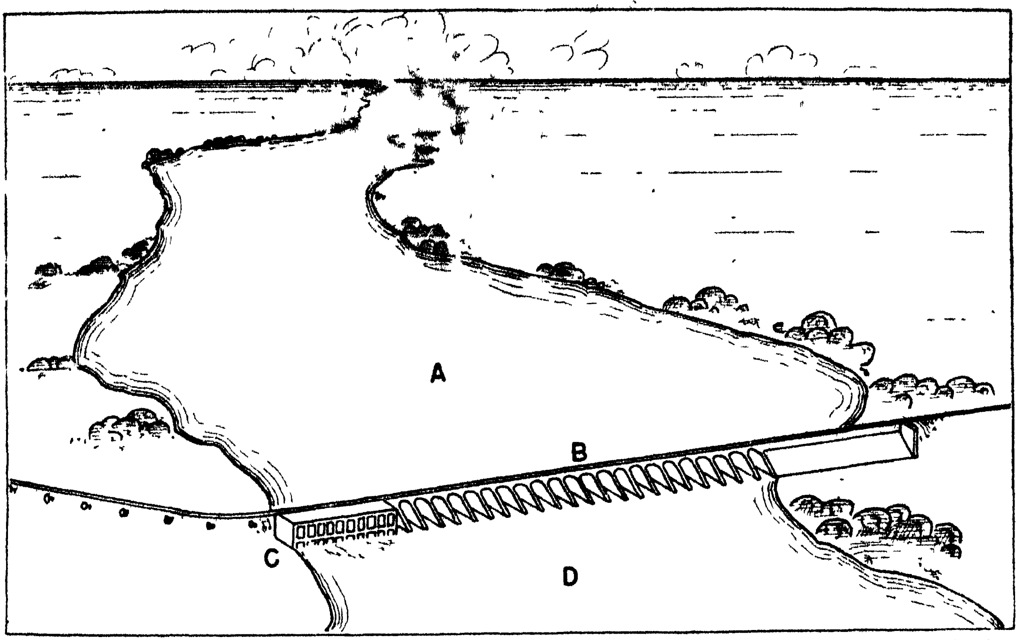
(B) Close-up view of a section of the penstocks illustrated to the left The Barberine Reservoir, illustration page 404, is higher in the mountains, and the power house indicated on the left is farther down the valley

In favorable cases such as where a large stream flows through a deep and narrow canyon, man can create a veritable artificial Niagara. Such is Hoover Dam in the canyon of the Colorado River, 730 feet high and reaching from canyon wall to canyon wall (see Illus. p 406) Thus, not only is great pressure created by raising the water to near the level of the dam, but also large

Courtesy Bureau of Reclamation, Washington, D. C.

Lake Mead and the Hoover Dam on the Colorado River. The dam is 730 feet high. The power plants can be seen at base of canyon walls at foot of dam. Tops of penstocks are shown in the lake above the dam. The resulting pressure per square inch on the turbine blades approximates 730 x .433 lbs.

enough quantities of water are made available to fill several penstocks. In lowland areas, streams tend to be sluggish and broad, but they often carry large amounts of water. Man cannot raise the stream level to such great heights by constructing dams across the rivers, but the large volume of water compensates for the lower fall. Examples of this type are the Keokuk Dam across the Mississippi and the Conowingo Dam across the Susquehanna (see Illus. above). This type of hydroelectric development is costly per unit of power produced unless associated with multiple uses such as navigation, irrigation, or flood control, and therefore, to date, the number of developed sites in this category has been relatively small.



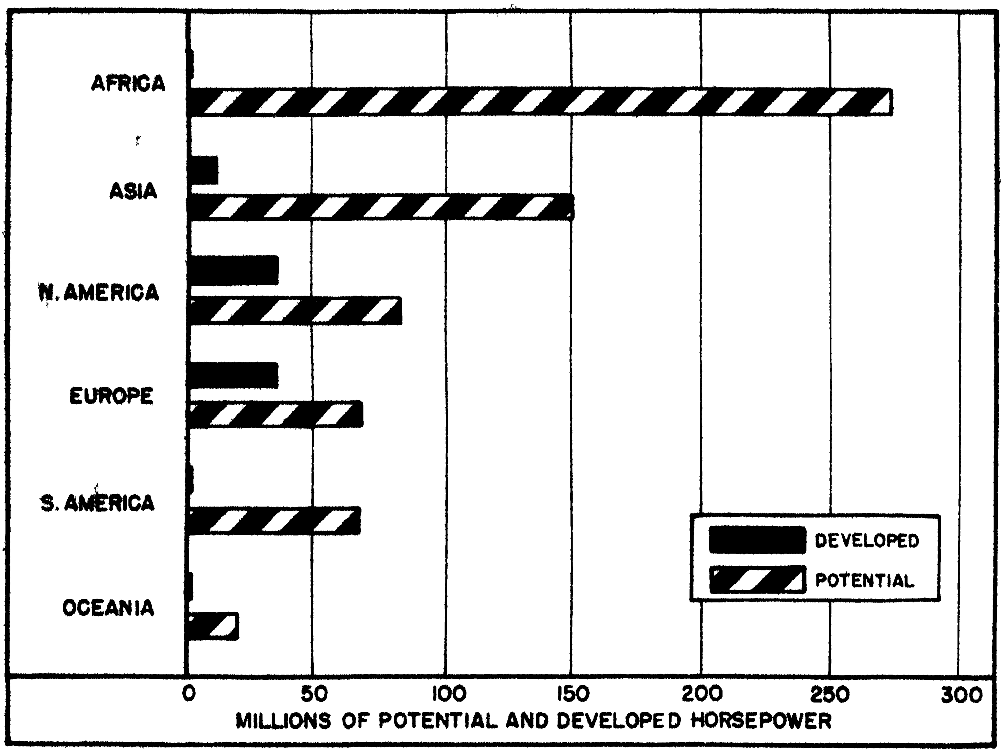
Sketch by Glenn Downey University of Nebraska

Pen sketch of the Conwingo Dam (B) and power plant (C) on the Susquehanna River, Maryland Developed head—drop from reservoir surface (A) to base of power plant (C) at water outlet downstream—is 89 feet Compute pressure upon turbine blades.

Characteristics of streams favorable for water-power development. From the above it should be evident that, given a market, the conditions most favorable for hydroelectric development would be a large flow of water coupled with a great height of fall, preferably provided by nature. Unfortunately, these conditions are not encountered in many places. Where such ideal conditions do not prevail, a relatively small flow of water should be accompanied by a steep gradient, or a gentle gradient should apply to a large quantity of available water.

For practical purposes, any power plant must be able to furnish a steady, dependable current month after month and be able to meet the heavy demands of peak-load periods, whether they be daily or seasonal. It is here that water-power development encounters one of its chief problems, since most rivers are subject to pronounced seasonal fluctuations in volume. The Missouri at Omaha, for example, has recorded a difference of nearly twenty feet between the high and low stages in a single year. Furthermore, the high stage of the river is marked by a sharp increase in velocity and therefore the difference in power potential is even greater than the difference in stages of water level. To make use of the potential power of streams characterized by great fluctuations in volume and flowing in broad valleys necessitates dams of such dimensions that the resulting lakes cover large areas of usable land. Power can be developed but the costs are so high that the whole project is likely to be uneconomic.

There is an intimate relationship between river regime[1] and the climate, topography, and vegetation cover of an area. In regions with equable rainfall, the river regime will show less fluctuation than in regions with pronounced wet and dry seasons, as, for example, in the tropical savannas or the dry interiors of the continents. Rivers that derive most of their water from mountain glaciers are generally more dependable than those that obtain their water from precipitation in a lowland area. Rivers that flow through well-forested mountain regions have more uniform volume than those flowing through mountain areas which have been deforested and where the surface litter has already been removed by erosion or burning.



Estimates by U. S. Geological Survey, Washington, D. C.

Graph to show estimated potential and developed water power resources of the continents as of January 1948. How does one account for the high potentials ascribed to Africa and Asia?

Potential water-power regions of the world. (See Graph on World Situation, above.) Where nature has provided storage basins in the form of lakes we find the most uniform type of river regime. Well-known examples of this type are the Niagara and the St. Lawrence rivers, both of which head in large lakes and are noted for their remarkable constancy of flow. The glaciated areas of North America and Europe, where numerous small lakes abound, also are characterized by streams of relatively uniform volume well adapted to power utilization. Small dams can be constructed at low cost and with slight hazards, and power at a minimum cost thus be made obtainable. For hydroelectric power it is always necessary to construct storage reservoirs to equalize stream volume and thus increase the power available during the low-water period. Contrary to popular opinion, the smaller power sites have not proved efficient in competition with the larger unit installations.

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[1] By *river regime* we imply the behavior of a stream through the normal course of a year, through low-stage and high-stage periods, and the rapidity or slowness with which those changes occur.

Those parts of the Canadian and Scandinavian shields which have been extensively glaciated are among the regions most favorable for water-power development. There, large lakes available as reservoirs are numerous, although in general the precipitation is moderate rather than heavy and the stream flowage is comparatively large due to the slight demands of the vegetation and the slow rate of evaporation caused by the low temperatures. In the portions of the country where low winter temperatures persist for several months, the problems connected with freezing and the necessity for maintaining steady flowage present difficulties to be surmounted. In severe weather ice may form within the penstocks, thus choking flowage to a greater or lesser extent. Ice masses may clog the outlet canals. Nevertheless these difficulties ordinarily can be overcome through careful engineering planning without adding greatly to the cost of producing electrical current.

Other areas favorable to hydroelectric development are high mountain areas, such as the Cascades, the Alps, the Caucasus, and the Himalayas. On most of these mountain slopes precipitation is heavy. In the Cascades it amounts to more than 80 inches per year at high altitudes on the western slopes, and in the higher parts of the Alps precipitation exceeds 120 inches. Rivers are well fed by snow fields and glaciers. Gradients are steep, and storage reservoirs either exist as glacial lakes or they can be constructed whenever necessary.

The tropical zones of high rainfall in South America, Central Africa, and the East Indies are rich in potential water power. Africa is especially well favored because much of the interior is a high plateau and practically all the rivers have falls and rapids near the coasts (see Table IX, p. 415). In South America, the greatest power possibilities occur in well-watered portions of the Andes and along the fall line which extends around the Brazilian Plateau. The large potential water powers of Africa, South America, and Asia have been but slightly developed as yet because they exist either where population is sparse or where modern industrialism has made little advance. In Asia, Japan and Korea have made great strides in hydroelectric development. In South America, Brazil takes the lead, but the percentage of power so far developed is low in comparison with the total potential. Much of Australia is too arid to produce large quantities of water power for the nation as a whole, although certain portions in the east and northeast have heavy rainfall. (See World Map of Climatic Regions and page 415.) It seems certain, therefore, that in so far as hydroelectrical development is concerned North America and Europe will continue to hold the center of the stage for a considerable time to come.

Development of water power in the United States. During colonial times water power played an important role in America, especially in New England, where lakes, falls, and rapids were numerous and where there was a nearly constant flowage of the rivers and even of the small streams, a large percentage of which were outlets of natural pondage produced by continental glaciation. Most of the towns had their own grist and saw mills driven by direct water power, and in many cases even the bellows of the smithy were activated by falling water. In the colonies farther south physical conditions were unfavorable for small-scale development; the rivers were larger and their flow was subject to greater fluctuations. As a result of these conditions, water power in that section of the country did not attain the importance in colonial life that it did in the north. In New England, the falls and rapids were early utilized to furnish power for the operation of factories (still called "mills"), and thus was made possible the early industrialization of that part of the New World (see Illus. pp. 337 and 341).

With the introduction of steam power based on coal, water power for a time declined in importance. Since 1900, however, the modern water-power industry based upon the generation of electricity has made rapid strides. In 1890 the installed water power was rated at approximately 1,280,000 horsepower, most of which was used without being transformed into electricity. In 1947, at all hydroelectric plants with a rated capacity of over 100 horsepower, the total installed capacity of water wheels and turbines had reached 24,206,000 horsepower. Even with this astounding progress, the country has developed only about 70 per cent of its rated potential. It has been estimated that with complete development of the water-power resources of the whole country the installed capacity would amount to 80,000,000 horsepower within continental United States.[2] Of the present production of electricity for public use in this country, about 35 to 37 per cent is derived from water power.

Water-power regions in the United States. Data obtained from the U. S. Geological Survey serve as the basis for this discussion of developed and potential water power. The amount of developed power is based on the installed capacity of water wheels at constructed plants, which averages two to four times the potential power at low flow at the same sites. This is of importance in comparing potential power with developed power and also in estimating the percentage of a nation's water-power resources which is utilized. For any country a rough estimate of the *ultimate* installed capacity of water wheels can be obtained by assuming it will equal the power available at mean flow and 100 per cent efficiency. The sites already utilized may be assumed to be the best sites in a country, except where development is regulated for the purpose of preserving scenery, as at Niagara Falls, or where good power sites may be too far from markets for economic development at this time.

The northern and northeastern parts of the United States, from Maine to Minnesota, are favored by numerous streams and lakes, generous precipitation, and nearness to population centers. Water power is developed more extensively there than in any other section of the country. As a unit enterprise, Niagara Falls ranks supreme but the swift-flowing streams between Lake Ontario and Montreal offer many favorable sites for large-scale hydroelectric development. This is true also where the streams are plunging from the Adirondacks and from the Catskills and the Appalachian Plateau to the lowlands bordering Lake Ontario and the Mohawk Valley. Even in that area, however, the hydroelectric power is insufficient to meet the demands and hence must be supplemented by numerous large steam plants to generate the needed electric power (see Illus. p. 344).

Another well-known site now fully developed is that of the St. Anthony Falls in Minneapolis, where the great flour mills were early favored by hydroelectric power; but even in the twin cities of Minneapolis and St. Paul the most important function of hydroelectricity is to provide supplementary current to meet the daily peak loads (see Illus. p. 411).

The Appalachians from Pennsylvania southward to Alabama make up another water-power region, one which reaches its maximum potentiality in North Carolina and Tennessee, where the mountains reach altitudes of 4,000 to more than 6,000 feet. Rainfall is abundant there, averaging from 60 to 80 inches per year. From the mountains, numerous streams of large volume and steep gradients descend to the adjacent lower lands of the Great Valley to the west and the Piedmont on the east, where population is relatively dense and the need for power is great. Still farther east, beyond the mountains proper, the streams pass abruptly from the hard rocks of the Piedmont to the soft rock of the Atlantic Coastal Plain. Above this line of contact, in the so-called "fall line zone" extending from Trenton, Baltimore, and Richmond to Columbia, South Carolina, and Macon, Georgia, are some of the best water-power sites of the region. In recent years large textile industries, attracted by available hydroelectric power, cheap labor, and proximity to raw material, have developed there and on the Piedmont.

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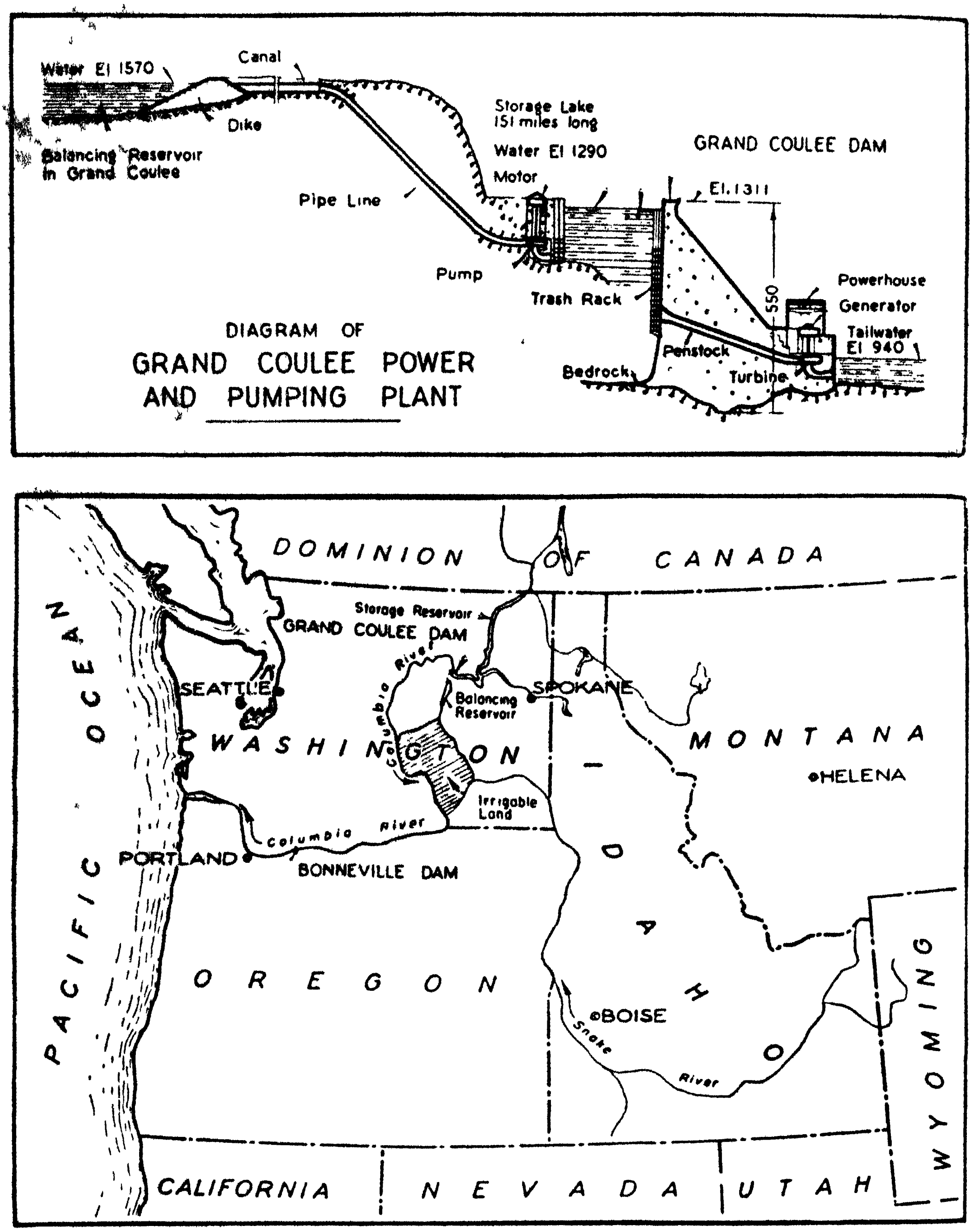
[2] *The Statistical Abstract of the United States for 1946*, p. 482.

Courtesy Minneapolis Chamber of Commerce.

The St Anthony Falls on the Mississippi, now completely harnessed for hydroelectric power Note the two dams, one at the left, the other near the center of the picture, and the large flour mills along the banks of the river

On the west side of the mountains, the Tennessee River Basin has become a major, highly developed, water-power region. There, however, under the auspices of the Tennessee Valley Authority, the development is of the multiple activity type; it is a unitized program involving flood control, navigation, and usage of the land. These are made practical by the dams which impound the water in order to reduce the great differences between high- and low-water stages formerly characteristic of the streams and to make use of the impounded water for the generation of electricity as it is discharged into the streams for the purpose of increasing navigability during low-water periods. With that has come the necessity of reducing the rate of run-off from the slopelands drained by the Tennessee and its tributaries. In order to accomplish this phase of the conservation program, an energetic educational campaign has been and is still being carried on whereby grain and livestock farmers are fully informed concerning the wisdom and economic soundness of a program of soil conservation that includes terracing, improvement of grass and timber cover, and the choice of crops, all employed to reduce to the minimum the

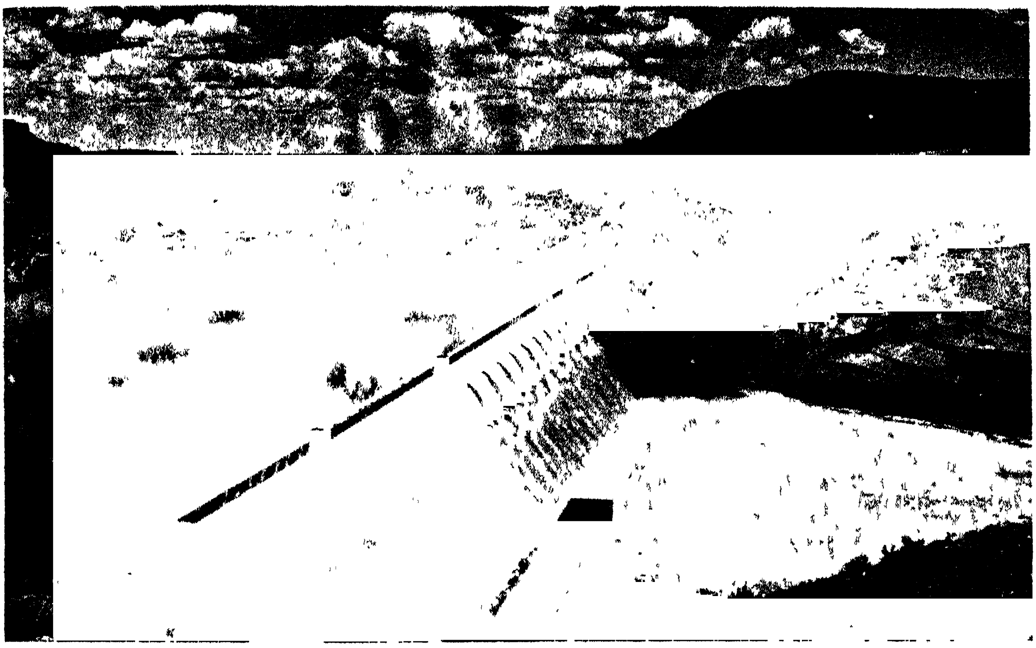


Courtesy U S Bureau of Reclamation Washington D C

Diagram of Grand Coulee Power and Pumping Plant and map of hydroelectric power locations along the Columbia River in Washington Note locations on map and the diagram of operations shown on upper drawing loss of soil by running water. Inasmuch as the program is one of multiple objectives, only part of the total cost of impounding the river waters into lakes by means of dams is chargeable against the hydroelectric power generated.

In the large central plains between the Appalachians and the Rocky Mountains, stream gradients are gentle and the river valleys generally are wide. Among the larger developed power projects, the Mississippi River at Keokuk was one of the earliest and is still one of the foremost in the Central Plains area. The rapids of the Missouri at Great Falls, Montana, are partly utilized by a large copper refinery. Furthermore, utilization of the upper Missouri by what is known as the Fort Peck Reservoir project has added another important development, and others are planned for early construction along the Missouri River and its major tributaries.

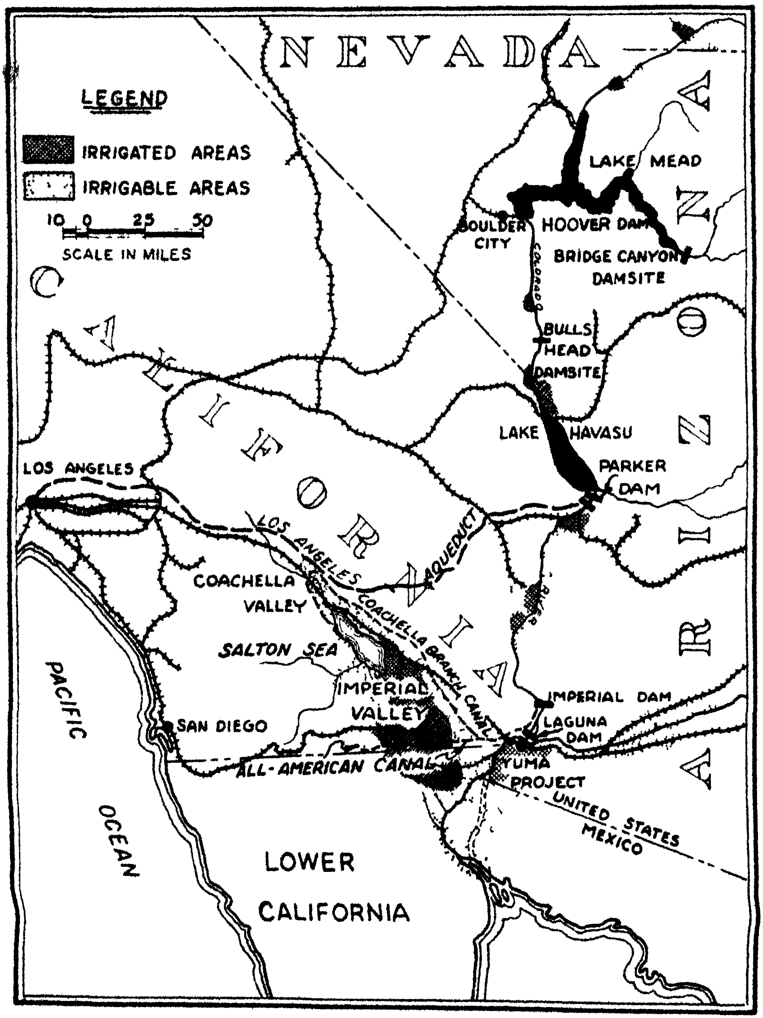
In the western section of the plains the average annual rainfall is less than twenty-five inches, and the streams, although subject to seasonal high stages and occasional flood conditions, have relatively small volume during most months of the year. For the most part, the natural conditions are unfavorable for large-scale hydroelectric development. In some places, however, streams flow over rock beds, channels are quite narrow, reservoir sites are available, and market demands for power justify development. Some such sites have been developed and power plants are in operation, notably on some of the large tributaries of the Missouri in Montana, Nebraska, and Kansas. Present plans call for extensive development of flood control, navigation, water power, and irrigation in the basin of the Missouri above Kansas City. Large powers can be developed, and if the project is constructed and managed on a



Courtesy U S Bureau of Reclamation, Washington, D C

The Grand Coulee Dam, Eastern Washington The largest concrete dam in the world This multiple-purpose dam raises the level of the Columbia River to facilitate irrigation pumping for the project The world's biggest hydroelectric generators are operated in the West Powerhouse, farthest from the camera unitized basis so that the expenses involved will be allocated to irrigation, flood control, and navigation, as well as to hydroelectric development, the economic feasibility seems assured. The net result will be greater agricultural and industrial activity throughout the area, and agricultural production will become stabilized to some degree, thus reducing the long-prevalent fear of years of almost complete failure caused by drought. Under a unitized program of the multiple advantage type proposed, available hydroelectric power as a by-product of irrigation will prove to be a stabilizing influence of high economic worth.

Potential water-power resources are greatest in the northwestern part of the United States. The western slopes of the high Cascades facing the moisture-laden air masses from the Pacific are noted for their heavy rains and winter snows, the latter alone exceeding thirty feet in some years.



After a map by C L Raum, U S Bureau of Reclamation, Washington, D C.

Map of Lake Mead, Hoover Dam, and irrigated lower Colorado River valley Note location of Imperial Valley and Salton Sea and the aqueduct through which water is carried to Los Angeles

TABLE IX

WORLD SITUATION AS TO DEVELOPED AND POTENTIAL WATER POWER, IN THOUSANDS OF HORSEPOWER (as of January 1948)

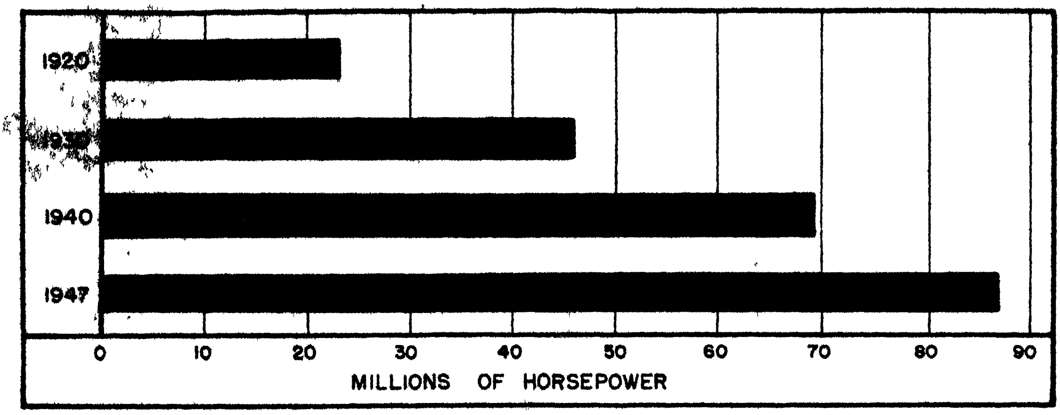
Continent and/or Country	*Developed*	*Potential*	*Percentage of Developed Power*
North America	35,849	84,400	42.47
Canada	10,491	32,000	32.78
Mexico	646	8,500	7.60
U. S. A. . .	24,206	31,700	39.75
South America	2,333	66,600	3.50
Argentina	75	400	[illegible]
Brazil .	1,520	28,000	5.42
Chile	322	3,600	8.94
Peru . . .	275	6,400	4.29
Europe	34,937	67,865	51.48
Italy .	6,250	6,000	104.16
France . .	6,100	6,000	101.66
Sweden .	3,820	4,000	95.50
Norway	3,800	10,000	38.00
Switzerland	3,700	3,600	102.77
Germany . .	2,600	2,000	130.00
Spain .	1,980	5,700	31.74
U. S. S. R.	1,900	11,000	13.57
United Kingdom	485	700	69.28
Africa	368	273,890	0.13
Algeria	105	300	35.00
Morocco	81	350	23.14
Belgian Congo	70	130,000	0.05
Rhodesia .	41	3,500	1.17
French Congo	—	50,000	0.00
Asia . .	12,059	150,600	8.00
Japan .	8,600	7,200	119.44
Korea	1,800	3,000	60.00
India and Ceylon	767	39,000	1.96
U. S. S. R.	312	61,000	0.53
China .	4	22,000	0.018
Oceania	1,281	20,150	6.37
New Zealand	670	2,000	33.50
Australia . .	352	1,000	35.20
Java . .	140	1,100	12.72
Philippine Republic .	65	2,000	32.50
WORLD TOTAL	86,900	664,000	13.08

Source: Estimates, *U. S. Geological Survey*, Washington, D. C.

Of the total amount of potential water power in the United States, 31 per cent is in Washington and Oregon (see Illus. p. 412). The Grand Coulee and the Bonneville projects along the Columbia River have added important contributions to available hydroelectric power in the rapidly expanding northwest. The absence of extensive coal beds and oil deposits in that section of the country enhances the importance of the water-power resources. In California the slopes of the Sierra Nevadas receive heavy precipitation from Pacific air. Although the tributaries of the Sacramento and San Joaquin are relatively small, their number and their swift descent give rise to comparatively great power potentials. As a result of the demands arising from the rapidly increasing population, the water-power resources of California are more fully utilized than are those of the other Pacific states. In California more than 50 per cent of the available potential is in use, whereas, for the Pacific Coast states as a whole, only about 25 per cent of the potential has thus far been developed. The potentials referred to in all phases of this discussion are those for which availability 95 per cent of the time is indicated.

The Colorado River flows through one of the most arid sections of the country, but melting snows in the headwater areas of the mountains and plateaus furnish abundant water. In most of southwestern United States power development is incidental to the conservation of water for irrigation, as is true at the Coolidge and Roosevelt dams on two of the southern tributaries of the Colorado. The Hoover Dam project on the Colorado River ranks as one of the largest irrigation and power projects in the world (see Illus. pp. 406 and 414). It is designed to equalize the flow of the lower Colorado in order to prevent loss of water during times of flood, to furnish water for municipalities and for irrigation throughout the year, to increase the area of irrigable land, and to produce cheap power for domestic and industrial purposes.

Water-power development in Europe. Italy, France, Switzerland, Germany, Norway, and Sweden produce about 75 per cent of the hydroelectric power developed in Europe. The combined production of



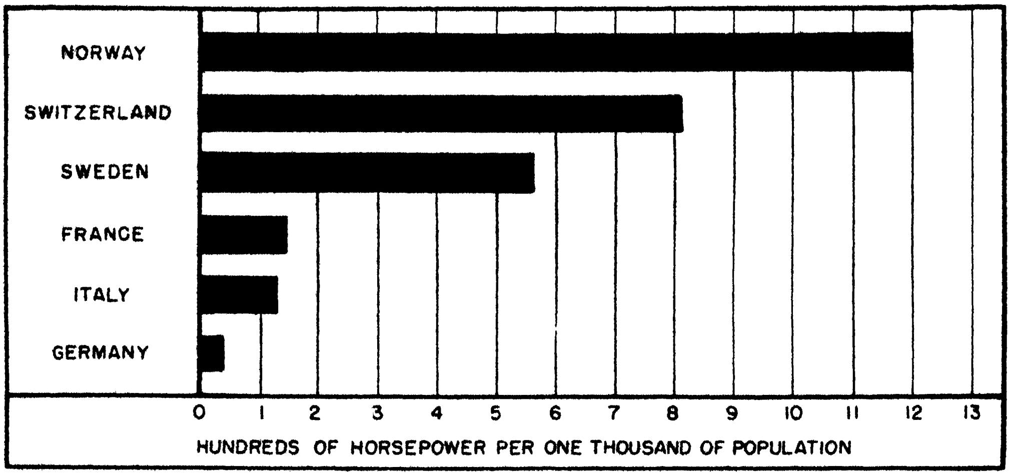
Estimates by U. S. Geological Survey, Washington, D. C.

(A.) Graph to illustrate rapid and pronounced increase in the developed hydroelectric power of the world since 1920. What was the percentage increase from 1920 to 1940?

these countries slightly exceeds that of the United States. (See Table on page 415.)

In Italy the absence of coal resources has served as an incentive for the development of water power. Much of the country is mountainous and receives considerable precipitation, especially in the Alps and the northern Apennines. The principal power sites in Italy are found in the mountains around the densely populated and industrialized Po Basin.

France ranks second in developed water power among the nations of Europe, the capacity of her installed water wheels being 6,100,000 horsepower in 1948 (see page 415). Small powers are widely distributed, but the principal areas of hydroelectric development are on the flanks of the Vosges, Alps, and Pyrenees and along the streams that head in the well-watered Central Plateau. The widespread availability of potential water power and the lack of important coal resources in most parts of the country are factors which have led to the development of hydroelectricity as an industrial necessity. The developed hydro-



(B.) Graph to show developed waterpower per thousand population as of early 1948 in the six European countries ranking high in this respect. How does one account for the comparatively low rank of Germany and the high rank of Norway?

electric power per capita in France is about four times that in Germany.

According to recent estimates, Sweden ranks third in Europe in developed water power, exceeding Norway by a slight margin. Sweden is fortunate in having extensive potentialities which can be readily developed because many of her streams are intercepted by lakes which serve as natural reservoirs to regulate stream flowage. Inasmuch as power is needed for the iron-mining industry of the north and for the lumbering operations throughout most of the country, with attendant demands for transportation, markets for electric power are near at hand everywhere. The principal handicap to be overcome is that of heavy ice formation in central and northern Sweden during a large part of the long winter period.

Norway ranks first among the European countries in developed hydroelectric power per capita and nearly equals Sweden in total power development (see Illus. B, p. 416). The country ranks second only to the U. S. S. R. in estimated potential water power. Development is favored by a mild winter climate along the western coast and by heavy snowfall on the interior uplands, which provides all-year run-off through the high gradient streams to the deeply indented coast. Low-cost hydroelectricity has long been recognized as a foremost economic asset for Norway, a factor that has favored the successful operation of technical manufacturing industries in that country.

Switzerland is the third member of the "Big Three" of the small countries that loom large in the development of hydroelectricity. Not favored by coal or other bulky raw materials for manufacture, the people of Switzerland have turned to skilled manufactures such as watches and precision instruments, wherein small amounts of raw materials, through skill and use of readily controllable power, result in products of high value. (See Table IX on page 415).

Germany, while rich in coal, found it economically advantageous also to develop her water-power resources. While the estimated potential water power of the country, based on the ordinary minimum flow of her streams, was only 2,000,000 horsepower, her *developed* power in early 1948 was reported as 2,600,000 horsepower. This is a concrete illustration of the fact that the published potentials are ultraconservative because they do not take into consideration the effects of construction of dams whereby the *mean* flow rather than the minimum becomes available. On the basis of early 1948 data, the amount of water power per capita developed in Germany was about 40 horsepower compared with 149 horsepower for France and 814 horsepower for Switzerland. (See Illus. B, p. 416).

Data for the Soviet Union are so sketchy as to make estimates of doubtful validity. In European Russia it is known that large power installations have been made since 1920, and it seems safe to accept the estimate that nearly 2,000,000 horsepower of hydroelectricity are now in operation. The potentialities are great, probably exceeding those of Norway. If all of Russia in Europe and Asia be considered as a huge unit, the computed potentialities may equal or exceed those of North America.

As a continent, Europe is rather fortunate in the distribution of her power resources. The countries with little or no coal, such as Italy, Switzerland, Sweden, and Norway, are rich in water power, while the countries weak in water power, such as England, Poland, and Germany, are rich in coal. Russia has large reserves of coal and potentialities of water power, which is true also, although in lesser degree, of Spain, Austria, and Czechoslovakia. The Balkan states have considerable potentialities of water power but are lacking in large-scale development. Denmark and the Netherlands are weak in both coal and water power but are within easy reach of both from competitive sources, a distinct economic advantage.

Water power in Asia. As may readily be observed from the list, Table IX, Japan is far in the lead in Asia from the standpoint of developed hydroelectricity. As with Germany in Europe, Japan has installed water wheels and dynamos that will deliver electric current in excess of the published potentials computed on the basis of minimum stream flow. The factors that have led to this high development include, of course, abundant precipitation, mountainous topography, and need for industrial power, to which must be added the zeal and energy of the Japanese people, a factor not to be overlooked.

Korea has made long strides forward in the development of water power in proportion to estimated potentialities. On the whole, however, one must recognize that hydroelectric development in Asia has made little progress in proportion to its potentialities.

Water power in Africa. As shown by the table on page 415, the outstanding continent in potential water power is Africa, credited with 41 per cent of the potential water power of the world and with only four-tenths of one per cent (0.4 per cent) of the developed water power. That it is a continent of great possibilities is unquestionable, but that does not answer either of two questions: "Why so much water power? Why so little development?"

In the first instance, we must recall that much of Africa is in the low-latitude belt of heavy rainfall and that much of the continent is plateaulike with sharp descent to the sea. Second, to date local markets have been small and scattered. The great markets are in connection with industrial areas, of which, so far, the nearest are in Europe. Thus it seems probable that hydroelectric development in Africa on a scale befitting the huge potentialities must await the establishment of large industrial centers within the continent or markets for hydroelectric power must be found outside the continent. The dream long held by some that power plants in the Belgian Congo will provide electricity for use in western Europe as far north as the British Isles may some day become reality.

Water power in South America. South America is in fourth place among the continents from the viewpoint of developed power, while on the basis of potentialities she is virtually on a par with Europe. Brazil has distinct leadership, being credited with 42 per cent of the potential and 63 per cent of the developed water power of the continent. In potential power, Brazil is followed by Peru, Argentina, and Colombia, in the order named, but in developed water power Chile ranks second to Brazil, followed by Peru and Argentina. The developed water power of South America is but 3.6 per cent of the reported potential. Inasmuch as most of the known power sites necessitate construction of expensive dams, distant from large markets, the expansion of hydroelectric power will probably proceed slowly. (See Table IX.)

Water power in Oceania. Oceania is rated as having developed 6 per cent of her potential water power, giving her a position in advance of South America in this respect. In development per capita, New Zealand holds first place in Oceania by a large margin, with 364 horsepower per thousand population compared with 46 horsepower per thousand population in Australia. Development in New Zealand is favored by mountainous terrain, ample rainfall, and demand for industrial power springing from an energetic and fairly numerous population. On the other hand, Australia is largely a continent of little rain, and in the eastern and northeastern sections where rain occurs and where water-power conditions appear most favorable, ample reserves of coal easily mined provide competition as a source of power not readily overcome.

Water power and industry. Water-power developments not only provide light and power for domestic purposes, but they usually sell a large percentage of their current to industry. With the aid of high-tension lines, electricity can be distributed over large areas. In recent years the distance over which it is profitable to transmit electricity has been increasing steadily and the networks of power lines are ever expanding. At present it is economically possible for a large power plant to transmit electricity from two hundred to three hundred miles. Nevertheless, there are a number of industries which tend to congregate around power sites because of their large demands for cheap power. Among these should be mentioned particularly the electrochemical industries, such as the manufacture of nitrates and calcium carbide, and the electrometallurgical industries, of which aluminum and special alloys are typical examples.

Cost of water power. The fact that no fuel need be purchased by hydroelectrical plants has led many people to believe that electricity can be produced and distributed by such plants almost free of charge, or at least much more cheaply than by coal-burning plants. This impression is erroneous and results from the fact that the public fails to take into consideration the huge expenditures necessary for the installation of great water-power plants. Furthermore, power sites usually are found considerable distances from industrial and marketing centers, thus involving costs of transmission from power plants to distribution centers. Inasmuch as these factors must all be taken into consideration in setting up hydroelectric establishments, the total cost of the electricity generated may be found to equal or exceed the costs involved in generation by steam plants. Still another factor not to be overlooked is that of gradual sedimentation of the reservoir and the resultant reduction of its capacity. Streams all carry varying amounts of sediment, which will settle to the bottom in the still waters impounded by a dam. The rate of filling will depend on the flowage of the stream, but since the best water-power streams generally are relatively swift owing to the high gradients, the load of sediment carried is usually comparatively heavy. Engineering safeguards may reduce the rate of filling and thus greatly prolong the life of reservoirs, but even so, they involve added costs of maintenance, and rates per kilowatt-hour must be computed accordingly.

The above is intended to aid readers to understand why electricity is not necessarily a low-cost form of power and to realize why dams and reservoirs should, wherever possible, be made to serve multiple functions, for example, irrigation, flood control, navigability, land use, and recreational resorts, as well as generation of electric power. Allocation of costs to the several functions served seems the equitable [illegible] of procedure.

Fortunately, the present problem is not generally a question of hydroelectricity *or* steam-generated electricity; we need and must have both. If *all* the possible water power in the United States should be fully developed, the amount of hydroelectricity would still fall greatly short of meeting the nation's power needs. Increasing efficiency of coal-fired steam engines is thus a factor of high industrial significance because low-cost power is essential to high production and general prosperity. Interconnected power systems of electricity generated by water power and by coal-burning steam plants may be expected to increase rapidly, with the result that homes and business in rural areas, as well as in the cities, will find electric service within their economic reach. This is another goal ardently sought in this age of distributable power.

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Chapter Twenty-four

THE IRON AND STEEL INDUSTRIES—FUNDAMENTALS OF THE INDUSTRIAL WORLD

In earlier chapters the mineral resources of particular value for construction purposes and for use as raw materials for manufacture without much change in nature have been considered. It will be recalled that the common rocks and minerals are of the first category, and such resources as asbestos, salt, sulphur, and the mineral fertilizers are of the second. The principal industrial processes involved in their preparation include fashioning for particular purposes and separating out of such impurities as are found associated with them. The third group from the standpoint of economic geography includes minerals which occur in nature as compounds which must be broken up in order to obtain the particular element deemed to be of economic value. The metallic ores are the typical representatives of this group. With a few exceptions, such as gold, platinum, and, to a lesser degree, tin, the metals occur in nature as chemical compounds which must be reduced to the metallic state by smelting—a manufacturing process. While in popular speech we refer to iron or copper mines, in reality we mean mines of iron ore or of copper ore.

In the industrial world of today iron is generally hailed as king—not without competition, it is true, but nevertheless, the commonly used expression, "the Iron and Steel Age," testifies to its wide acceptance. In business circles the fluctuation in demand and in prices for steel constitutes a barometer whereby economic trends are interpreted by a larger following than is generally true of any other metal. Other ores of major importance which likewise must be reduced to metals by smelting include copper, lead, zinc, aluminum, and tin. Nations well supplied with mineral fuels and with the ores of the materials named have the major basic resources needed for industrial achievement.

While the six metals named above are the most widely used in large quantities, others are almost equally essential to industry because of particular qualities they impart when used as alloy materials with those of the major group. In this latter class those used for tempering and hardening steel are the best known, for example, manganese, nickel, cobalt, chromium, tungsten, and vanadium. Without alloys, many of the metallic products now in common use would be of little value because desired qualities, such as cutting edge, elasticity, hardness, and resistance to rust, could not be attained.

The iron ores. The term *ore* refers to a natural mineral compound, usually metallic, from which the metal may be extracted to economic advantage. The economic connotation applies to the foreseeable future as well as to the present. Metallic compounds which are so widely disseminated through the rocks that there is no hope of successful extraction, such as the iron rust which gives color to many soils and subsoils, are not classified as ores. Four principal groups of iron compounds occur in bodies large enough to be worked as ores: hematite, magnetite, limonite, and siderite. Although these compounds are of common occurrence in rocks and soils, only in scattered places do they occur in large masses with relatively small percentages of impurities. Most of the world's supply of iron is obtained from such masses, known as *ore bodies.*

HEMATITE is the most important industrial iron ore in the United States. When pure, it contains nearly 70 per cent metallic iron; but where mined it is always found mixed with some impurities, so that the actual percentage of available iron may be less by 20 per cent or more. For example, the hematite mined in Minnesota and Wyoming in recent years has averaged from 51 to 52 per cent metallic iron. Hematite is mostly reddish or so-called ocher red, although some is almost black or even bluish. While not the most widespread of the iron oxides, in the United States hematite ranks first in industrial importance because of its relatively high grade and the ease with which it can be mined and smelted.

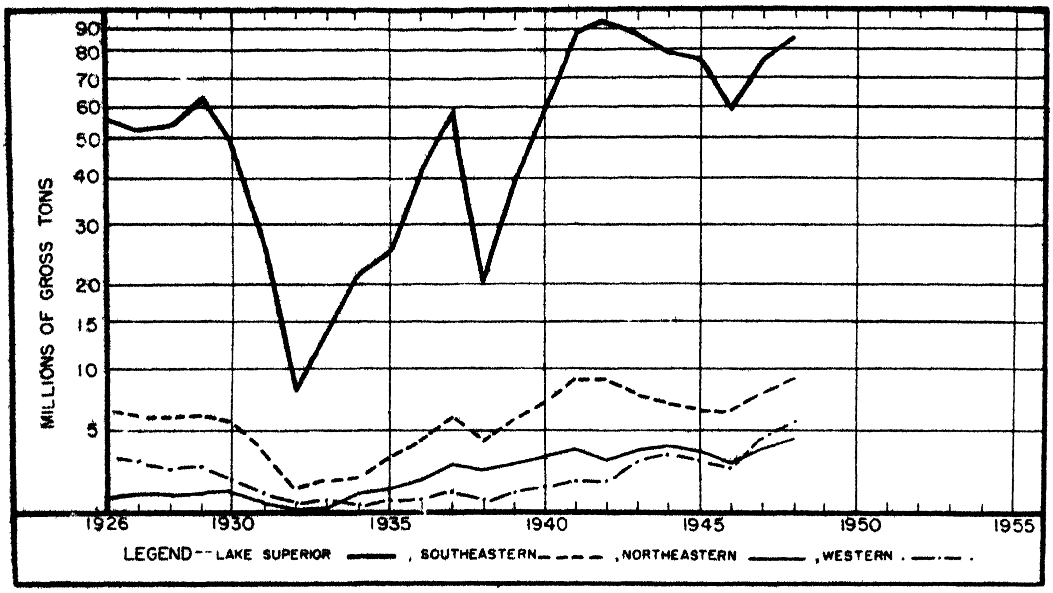
MAGNETITE is the richest of the common iron ores. Some varieties act as natural magnets and therefore are designated as *lodestones.* The color is darker than that of hematite or limonite, varying from deep dark brown to greenish black. When pure, magnetite contains 72.4 per cent metallic iron, but in actual mining operations the ore is considered to be high grade if it yields more than 60 per cent metallic iron. Magnetite recently mined in Nevada is reported to have yielded 65 per cent metallic iron, while some semialtered magnetite from Utah yielded only about 54 per cent metallic iron.

LIMONITE is the most common of the iron oxides. It is a chemical compound in which water is an essential constituent. It is widely distributed over the earth and occurs in varying degrees of hardness; its color ranges from yellow to dark brown. Limonite commonly gives a yellowish or brownish color to the subsoil, but it is called an ore only where it occurs in bodies large enough for successful mining operations. Its chemical composition has been found to be so varied that some metallurgists question the accuracy of its classification as a separate and distinct mineral. When pure it may contain nearly 60 per cent metallic iron, but as mined it is usually found to be mixed with impurities which reduce the recoverable iron content to below 50 per cent. The limonite mined in Alabama in 1946 was reported to yield on the average 44.6 per cent metallic iron. The same kind of ore mined in France and in England is deemed satisfactory if it yields above 35 per cent metallic iron.

The three ores thus briefly described constitute the principal sources of primary iron in the world today. All three are essentially chemical compounds, in varying ratios, of the elements iron and oxygen. In the earlier period of development of the iron and steel industry, much dependence was placed upon a carbonate of iron known as *siderite,* consisting chemically of iron, carbon, and oxygen ($FeCO_3$). Pure siderite contains about 48 per cent metallic iron, but the ore actually mined is mixed with impurities which materially reduce its iron content, in some cases to less than 35 per cent. Although the percentage of metal is not so high as in the oxide ores, siderite is usually free of undesirable impurities and hence is easy to smelt. Siderite was in large measure responsible for the quality of steel products which long ago gave Sweden and England their high reputations in the manufacture of sharp-edged instruments. This reputation still endures and is a valuable business asset to the cutlery industries of those countries.

Distribution of iron ores in the United States. The production of iron ore in the United States occurs in four main districts:

the Northeastern, the Southeastern, the Lake Superior, and the Western.

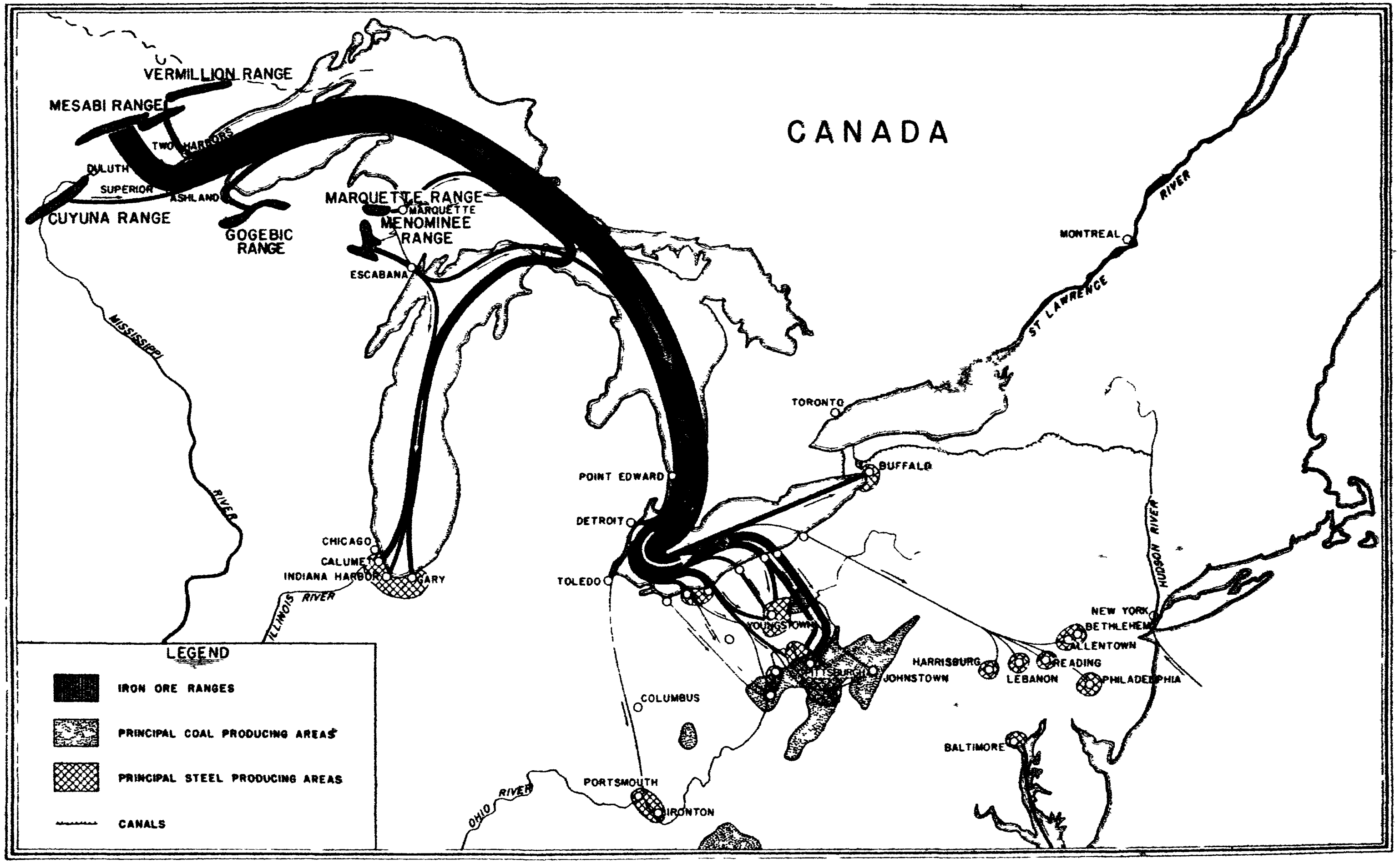


Annual production of iron ore in each of the four generally recognized districts of the United States since 1926. Note the consistently predominant position of the Lake Superior district and the marked rise in production shown for the western states since 1940.

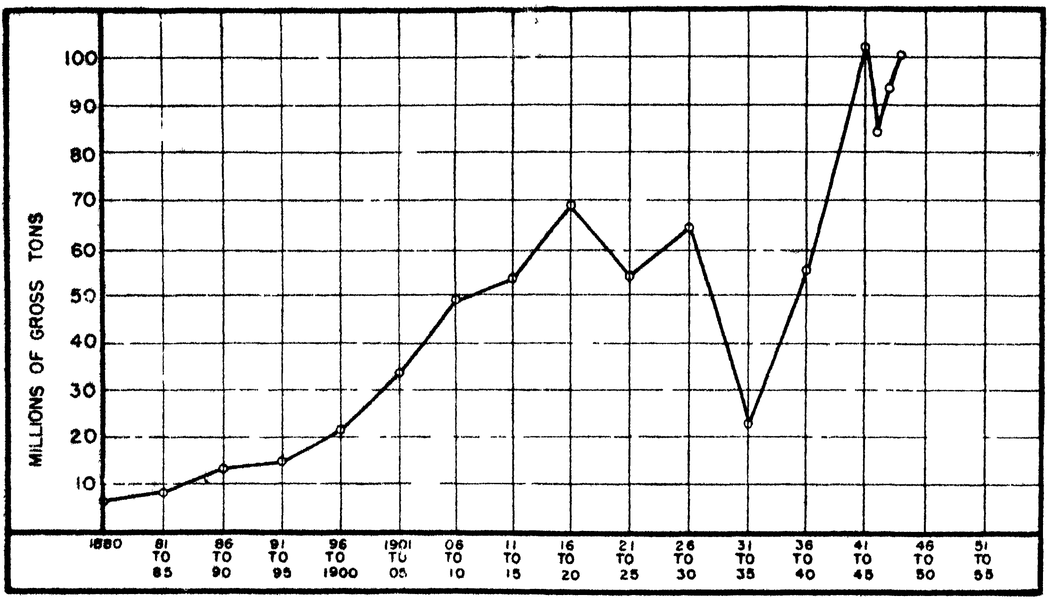
The Northeastern District. The two principal areas of iron-ore production in the northeast are the Adirondacks region of New York and the Cornwall area of Pennsylvania. The latter extends across New Jersey into southeastern New York and is often referred to as the southeastern New York-New Jersey field. The total output of ore in the northeastern states has been 3 to 4 million tons annually during recent years. Magnetite, the principal ore, has a relatively high market value per ton because of its quality and accessibility to markets. The ores of New York and eastern Pennsylvania are important local sources for the near-by smelting industries, although total production is relatively small compared with that of some of the other districts (see graph above).

The Southeastern District. The only important mining areas in the southeast are near Birmingham, Alabama, and Chattanooga, Tennessee. The average annual output of ore of these two areas is about 6 to 8 million gross tons. Hematite is the principal ore, but associated with it are considerable quantities of limonite. The southeastern district has the advantage of nearness to the coking coal found in the Appalachian Plateau immediately westward. The Birmingham and Chattanooga centers meet important demands for iron in southeastern United States.

The Lake Superior District. The producing area of the Lake Superior district is limited to the peninsula of upper Michigan, northern Wisconsin, and northeastern Minnesota. This area regularly furnishes 80 to 85 per cent of the total iron-ore output of the United States. Hematite is the predominant ore occurring in large bodies and generally soft enough to be mined with little use of explosives. The greater part of the output comes from long, low ranges, the principal ones being the Mesabi, Vermilion, and Cuyuna ranges of Minnesota and the Penokee-Gogebic, Marquette, and Menomonee ranges of Wisconsin and Michigan. The Mesabi is by far the most important, in most years accounting for more



Map of the well-known iron ore ranges of the Superior district the principal coal-producing areas of the Appalachian field, and the steel-producing districts, together with the flow of iron ore to the steel centers Note the wide distribution of the Lake Superior ores than 65 per cent of the total output of the United States. The average amount of ore mined annually in this district during the six-year period, 1923-1929, was 54,350,000 long tons. In 1948 the production reached a total of 82,500,000 tons, or 82 per cent of the total national output for that year. The so-called Class I ores of the Lake Superior district are expected to last for not more than 20 to 25 years, but there are reserves of low-grade ore sufficient to supply the needs of the nation for more than a century to come (see Illus. p. 423).



Graphic illustration of the production of iron ore in the United States since 1880. Five-year averages only given until 1941, yearly production since then Note the low output during the 1930's and the greatly increased production since 1938. Suggest reasons in each case.

The Western District. The western district includes all the states from the Rocky Mountains to the Pacific Coast. Within that vast area the principal iron-ore producing states are Utah, Wyoming, California, and Nevada, although stores of ore have been reported in varying amounts in other states and local production has been attained in some years. The four states named are important sources of ore to be smelted into pig iron for conversion into steel, while the smaller output of ore of the other states in the district is used principally as flux in smelting operations for copper and the precious metals and has some importance in finishing raw material for foundries and other local industries.

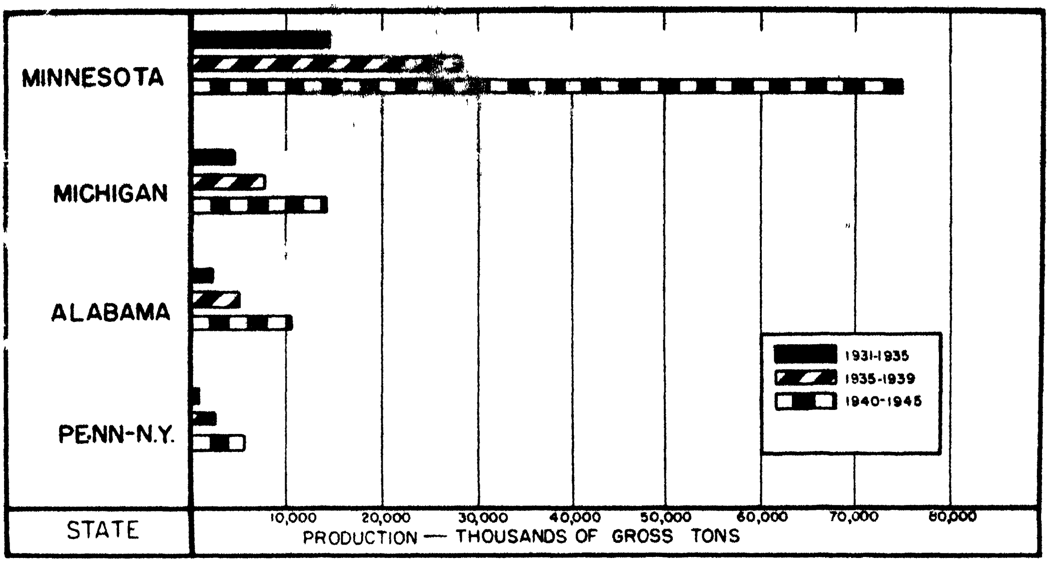
A recent development in the Western district that is indicative of the rapid industrial growth in that section of the United States is the establishment of large integrated steel plants at Geneva, Utah, and at Fontana, California. The Geneva plant obtains its major supply of ore from Iron Mountain near Cedar City in southwestern Utah, a source used to some extent by the Fontana plant as well, despite the long rail haul involved. Recently the Fontana interests have acquired a large store of ore at Elk Mountain which, when fully developed, will provide the ore needed for the smelters and steel mill at Fontana, which is strategically situated to serve the large and growing industrial area of southern California.

The Western district, with but three complete furnaces and steel plants, at Pueblo, Colorado, Geneva, Utah, and Fontana, California, nevertheless has more than

200 plants using pig iron and scrap metal for manufacture into structural iron and other local uses. These plants produce 1,300,000 to 1,600,000 short tons yearly, with markets still expanding.

A summary of production of iron ore in the United States. The average annual output of iron ore in the United States dropped from about 60 million tons during the 1920's to less than 40 million tons during the following decade and then rose to an average annual output of 109 million tons during the 1940-1945 period. The yearly output has been subject to wide fluctuations; for example, in 1932 only 9,847,000 tons were mined, whereas in 1939, 51,732,000 tons were mined and in 1948, 101,350,000 tons (see Illus. p. 428). The average price of ore at the mine has risen gradually from a low of about $2.40 per ton in 1941 to $3.53 in 1947. On the average, more than 92 per cent of the ore mined is hematite. Magnetite usually constitutes about 5 to 6 per cent of the total, while limonite is third with about 1.5 per cent. The output of siderite is small, virtually none being produced in some years.

The three states leading in production of iron ore are Minnesota, Michigan, and Alabama, the first-named regularly producing more than one-half of the output of the entire country (see Illus. below). Fourth and fifth places are ordinarily held by Pennsylvania and Wisconsin, respectively, while a number of other states produce lesser quantities.



Production of crude iron ore in the principal producing states of the United States by average annual output indicated for the three successive five-year periods. What must have been true of the effect of World War II upon the unmined iron ore resources of the country?

The steel industry of the United States. Iron ore has been mined within the present borders of the United States since the beginning of the colonial period. The earliest colonists felt keenly the need for local iron supplies. Transportation across the Atlantic was slow and long, and delays were an economic handicap because needs could not always be foretold long in advance. The New England ores were mostly bog-iron deposits (a form of limonite) of low grade, but they sufficed for the operation of numerous small smelters. As a result of this development, by the end of the seventeenth century New England boasted a sizable iron industry. The output was used for the manufacture of iron fittings for ships, agricultural implements, builders' hardware, and iron kettles. The last-named were indispensable to the colonial household for cooking, rendering lard, and making soap. However, demands were not large because wood was then the material most used in the construction of ships, implements, homes, and business structures.

The period wherein wood was the predominant material for buildings, carriages, mills, and fuel continued in the New World until about 1840, by which time timber cutting had reduced supplies available where needed, thus causing a demand for iron and for coal. The small deposits of low-grade iron ore soon proved inadequate to meet the rapidly expanding demands, and under the pressure of need the richer deposits of magnetite found in New York and Pennsylvania were exploited and numerous iron and steel plants developed there and in Maryland, thus making that section the chief center of the iron industry of the United States. During the early stages of this development charcoal was the chief smelter fuel, but with diminishing supplies of wood for charcoal, it was found that anthracite could readily be used instead; thus anthracite contributed substantially toward making eastern Pennsylvania the leading center of the iron industry until after the Civil War.

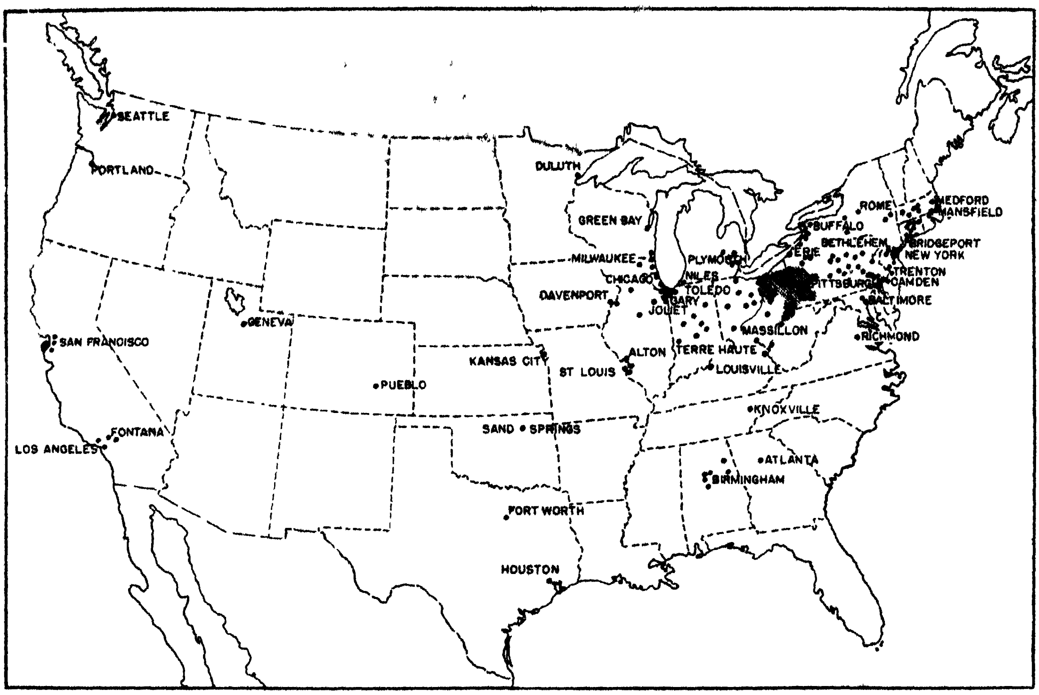
By 1860 American mills were turning out over 200,000 tons of iron rails per year. The development of the West created great markets for iron and steel products, and coke made from the bituminous coal of western Pennsylvania was found to be cheaper and better for iron- and steelmaking than anthracite. These factors caused the center of the iron industry to shift westward. The center of the steel industry from the small beginnings in the seventeenth century had shifted from the Atlantic Coast to eastern Pennsylvania, and finally across the Alleghenies. Pittsburgh thus became the nation's "iron and steel capital," a position it still holds in the public mind. Measured by present standards, growth was slow until after 1880. In 1879 the total amount of iron ore mined in the United States was but 6,308,000 tons. The sharp increase in annual production of iron and steel began with the shipments of ore from the head of Lake Superior about 1884, increasing slowly at first in total tonnage; but by 1890 the low-cost ores of the Superior region had attained dominance in the American iron and steel industry.

Since 1890 we have quite literally entered upon a steel age. Wood has been almost entirely displaced by steel in the construction of ships, railway cars, motor vehicles, agricultural machinery, and factory equipment. Skyscrapers are gigantic steel structures wherein little wood is used. Even office equipment is made largely of steel. In every important productive industry steel is an essential. So closely related is the iron and steel industry to all other commercial enterprises that it is generally regarded as the foremost business "thermometer"; the trend in the iron and steel trade is accepted as a reliable index of business conditions.

Iron and steel centers: THE UNITED STATES. There are now a few centers of universally recognized leadership in the smelting of iron ore and the manufacture therefrom of iron and steel, the foremost ones being the Pittsburgh-Youngstown and the Gary-South Chicago districts. The Lake Erie region from Buffalo to Detroit may be considered as being an extension of the Pittsburgh district, since the two have many factors in common. Taken together, the output of iron and steel from the plants near or on Lake Erie and from those at the head of Lake Michigan constitutes by far the major part of the production of the United States. (See Illus. p. 423.)

Iron-ore transportation in this country is dominated by the Great Lakes water route, supplemented by short rail haulage from the lake shores to the smelters. Lake transportation is cheap, and therefore, although distances are relatively great, the ore is available at low cost for the coal of the Pittsburgh-Youngstown district and of Illinois. The importance of the Great Lakes can hardly be overemphasized in accounting for the prominence of the great iron-manufacturing cities from Pittsburgh and Buffalo in the East to Chicago in the West (see Illus. p. 423 and below).

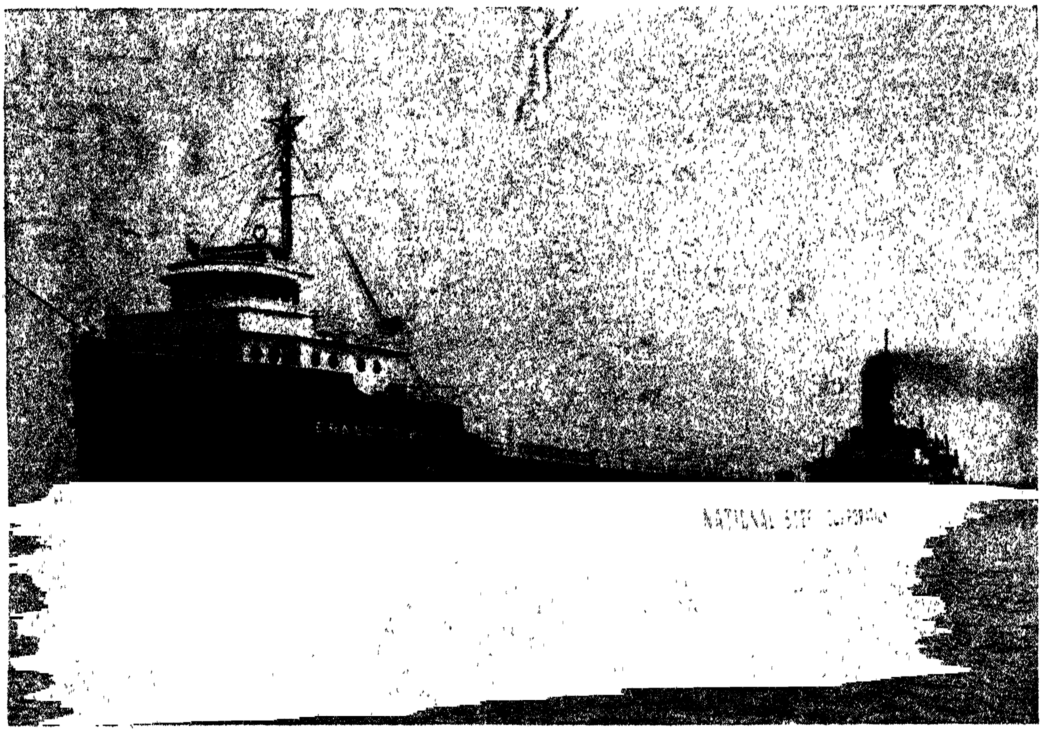
THE PITTSBURGH-YOUNGSTOWN DISTRICT. The leadership of the Pittsburgh-Youngstown area must be attributed, however, to several factors in addition to lake transportation. The early start of the area gave an initial competitive advantage, which is a continuing important factor in its present industrial importance. Prior to the great exploitation of Lake Superior ore, Pittsburgh had achieved prominence in the iron industry through utilizing ores near by. The bituminous coal in adjacent mines was found to make coke of excellent grade, and the abundance of natural gas near at hand furnished the cheapest, most efficient fuel for steam purposes.



Map of the principal steel finishing mills of the United States. Note that many steel finishing mills are located at points distant from ore-producing centers. What is evidently the raw material for manufacture used by the steel finishing mills?

These advantages enabled Pittsburgh to wrest supremacy in the iron and steel industry away from eastern Pennsylvania and, with a group of adjacent cities, to hold supremacy west of the Alleghenies. Compared with the newer centers farther west, such as Toledo, Gary, and South Chicago, Pittsburgh has some advantage in her nearness to the great eastern markets. This, combined with her early start, has retained for her the position of supremacy in the face of keen competition. The Pittsburgh-Youngstown district ranks as one of the greatest iron-smelter and steel-mill centers in the world, and it is axiomatic that businessmen of Europe as well as those of the United States view the activities of the iron and steel plants there as being among the most important business indexes of the nation.

THE LAKE ERIE DISTRICT. The cities on Lake Erie have the great advantage of easy access to the northern Appalachian coal and coke, direct receipt without reloading of the iron ores from the Lake Superior area, and choice between water and rail shipment for the products. Furthermore, several of these cities, such as Detroit, Buffalo, Cleveland, and Toledo, have important steel-consuming industries. In recent decades this region has become an important competitor of the Pittsburgh-Youngstown district. Economically, its geographical location is favorable, and continued growth of its iron and steel industry may be expected with the expansion of the steel-consuming industries on and near Lake Erie.



Courtesy M A Hanna Corporation.

A modern ore boat in the iron ore carrying trade in the Great Lakes. These boats are constructed so as to facilitate rapid loading and unloading of ore cargo, and thus increase the hours and days available for actual movement of ore. A quick "turn around" is a mark of efficiency and reduces the per ton cost.

THE CHICAGO DISTRICT. Ranking second to the Pittsburgh-Youngstown district is the area near Chicago at the head of Lake Michigan, which includes the cities of Gary, Indiana Harbor, and South Chicago (see Illus. p. 427). The Chicago district is favored by ore cheaply available, by low-cost coal for heating and steam, and by great interior markets. The railroad demands for rails and rolling stock have been heavy because of the vastness of the territory served. The recent growth of cities in the interior has called for large quantities of structural steel. Seated in the heart of grain-farming America, Chicago is the natural source for the iron and steel needed in manufacturing agricultural implements. With all these advantages there are two serious disadvantages, compared with the Lake Erie and Pittsburgh areas, namely, smaller demand and lack of high-quality coking coal. The coal used for heat and power comes mostly from Indiana and Illinois. This is a splendid low-cost steam coal but it is not of good coking quality. It is necessary therefore to bring coke from the Appalachian bituminous fields of Pennsylvania and West Virginia (see Illus. p. 356). The markets for iron and steel from the Chicago area are not as great as those of the Lake Erie and Pittsburgh areas, which serve not only the most densely populated section of the United States but also most of the nation's shipbuilding yards located near the eastern seaboard. Although the Chicago district may not attain supremacy in the iron and steel industry of the United States, its natural advantages are so great and its trade area so large that it seems certain to retain its present high rank.

Courtesy American Iron and Steel Institute

General view of a blast furnace, Bethlehem Steel Company, Bethlehem, Pennsylvania. Note the loading skip at the left of the building, the charging platform at the top, and, at the right, the stoves used for heating air to be injected into the blast furnace. Iron ore, limestone for flux, and coke are brought to the top of the furnace by means of the loading skip and there dumped as a charge.

The Birmingham District. Birmingham, Alabama, has often been called the "Pittsburgh of the South." While this title is somewhat misleading because Pittsburgh is primarily a steel city and Birmingham produces mostly pig iron and various kinds of malleable and cast-iron products, the Alabama city far outranks all others in the South in such products. Chattanooga, Tennessee, is an important second center in the same general area (see Illus. p. 427). Both centers have iron ore, coking coal, and limestone near at hand. The availability of these fundamental raw materials has led to the development of a great iron-manufacturing district to serve the needs of southeastern United States more efficiently than could be done by the northern plants.

Steel development has lagged in the Birmingham district because in the main the same capital interests that operate the blast furnaces of the southern centers also own the steel plants of the north. Since steel is much more valuable per unit of weight than is pig iron, and inasmuch as the mills of the north have the capacity to turn out more steel than the whole country demands in normal times, capital has not deemed it economically wise to attempt large-scale steel production in the southern centers. The outlook justifies the belief that, with the development of the South, Birmingham and Chattanooga will continue to expand as iron-producing cities and that much of the steel will be supplied from the old, established northern centers.

THE EASTERN PENNSYLVANIA DISTRICT. Although the major centers of the industry have long been west of the Alleghenies, some of the older eastern districts have maintained important positions. When anthracite was the chief smelting fuel, eastern Pennsylvania became the foremost iron and steel center in the country. When coke from bituminous coal displaced anthracite and the Pittsburgh district forged to the front, the established iron and steel plants near Harrisburg, Allentown, and Bethlehem found it necessary to turn to high-quality speciality manufactures, a field of business that proved to be highly profitable. High-grade ores are furnished by the mining area of the Adirondacks and northest Pennsylvania. Only a comparatively short haul is necessary to bring coke and coking coal from the producing areas in western Pennsylvania and West Virginia. The densely populated territory from Boston to Richmond serves as a front-door market of first magnitude for quality steels ranging from steel rails and armor plate to the finest cutlery steel for razor blades. This combination of favorable factors—ore resources, low-cost fuel, and great adjacent markets—gives assurance of continued prominence of the Allentown-Bethlehem district in the iron and steel industry.

OTHER DISTRICTS. The Atlantic seaboard, scene of the earliest iron industry in the colonial period, is apparently undergoing a renaissance that may again give it high rank. Foreign ores from Sweden, Newfoundland, Cuba, or South America can be shipped there by all-water routes, and much scrap iron is obtainable from the near-by manufacturing and transportation industries. These conditions, together with great markets, have led to the development of specialized iron and steel manufacturing in the coastal cities from New York to Boston. One of the largest plants in the country is located at Sparrows Point, Maryland, on Chesapeake Bay. The Atlantic Coast cities, particularly in the Baltimore district, are likely to become increasingly important in the American iron and steel industry during the next quarter of a century.

The city of Pueblo, Colorado, has the distinction of being the oldest iron-ore smelting center and steel plant west of the Mississippi River. Most of the ore used in the industry at Pueblo is mined in southwestern Wyoming, where a high-grade hematite occurs in fairly large quantities. Good-sized quantities of ore have in recent years been shipped from southern Utah to Pueblo. Coking coal is obtained from the Trinidad field of southern Colorado, not far from Pueblo (see Illus. p. 356). It has been found cheaper to bring the ore from Wyoming to Pueblo, and even from southern Utah, than to haul the coal and coke to the ore. Because of the available reserves of coking coal and the accessible iron ore, coupled with the growing markets of the Rocky Mountain area, the Pueblo region can be expected to maintain its place as an important producer of iron and steel.

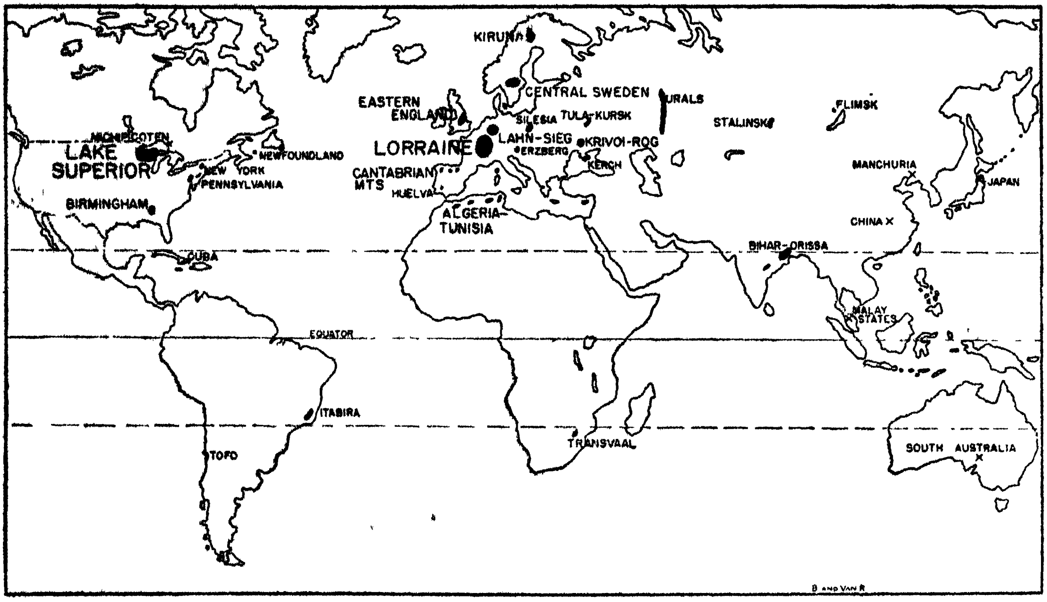
West of the Rocky Mountains are the two great centers already mentioned (page 427), Geneva, Utah, and Fontana, California. While there are numerous small plants for the conversion of pig iron and scrap into structural forms needed in industry and for construction, until very recently no complete iron and steel plants have existed west of the Rockies. Inasmuch as coking coal can be mined and large stores of high-grade iron ore have been discovered and are now being exploited, it seems that these plants will serve a vast area to economic advantage. With the expanding industrialism characteristic of the Pacific Coast states, it seems quite probable that additional complete plants may be established in the not too distant future.

Courtesy American Iron and Steel Institute

General view of the new steel plant at Geneva, Utah, a few miles south of Salt Lake City. Note stoves and blast furnaces at left, main steel plant prominent in center foreground. The ore is shipped there from Cedar City, Iron County, in southwest Utah. Nine open-hearth furnaces operate with rated capacity of 1,284,000 tons of steel per year.

Iron-ore resources of the world. Iron is one of the most common elements of the earth's crust and ore bodies of the metal are widely scattered. Although large reserves of iron ore have been found on every continent, exploitation has been confined to those of relatively high quality and those most favorably located with respect to power resources, transportation facilities, and market demands. Large stores of unmined ore are known to be present in South America, Africa, Australia, and Asia, but exploitation has thus far been on a small scale compared with the heavy output of the major centers of Europe and North America. Even so, the world output of iron ore, which during years of high industrial activity has exceeded 200 million metric tons per year, has been credited to over fifty countries, with nearly half of them producing more than one million tons yearly. During the decade, 1936-1946, the total output of the six leading ore-producing nations—the United States, the Soviet Union, France, the United Kingdom, Germany, and Sweden—provided 82 per cent of the world's iron-ore production. In this presentation we must confine ourselves to the relatively few important centers of output in each continent.

North America, excluding the United States. Commercial production of iron ore has been characteristic of Cuba, Mexico, Newfoundland, and Canada for a number of years, but output has been relatively small until recently. Newfoundland has consistently produced close to the million-ton mark without any definite change in trend being apparent. Cuba's output has remained quite steady at from 160,000 metric tons in 1940 to 159,000 in 1946; fluctuations occur, but no definite trend is shown. The output in Mexico increased from 111,000 tons in 1940 to 275,000 tons in 1946, since reserves of ore have recently been estimated as 212,550,000 metric tons, there seems to be strong likelihood of a continued upward trend. Recent developments in Canada appear to assure a strong upward trend during the years ahead, a trend manifest in the rise in output from 376,000 metric tons in 1940 to 1,434,000 metric tons in 1946. The greater part of this steady development has occurred in the Lake Superior region, but recent discoveries in the northeastern Quebec province appear to have located huge stores of high-grade ore for which plans for exploitation are already well advanced.



Map showing the principal iron ore-producing areas of the world. Note particularly the number of production centers shown for Europe and the recently developed centers indicated east of the Urals. Southern Utah and California have active exploitation of iron ore but areas and quantities are as yet not large enough to illustrate on this map.

South America. Stores of iron ore have been reported at various times from every country in South America, but the only two centers of active exploitation are in Chile and Brazil (see map above). Chile's principal mining center is not far from the coast at the El Tofo mines northeast of Coquimbo. The reserves are large, the ore is of high quality, averaging about 60 to 63 per cent iron, and loading costs are low because of downhill haul to the seaport, Cruz Grande. At this seaport, one of the largest and most modern sealoading ore docks, a development owned and operated by one of the great American steel companies, is used to load vessels for direct shipment to the iron and steel plants at Sparrows Point, Maryland. Chile is making a beginning in the reduction of ore and manufacture of iron and steel but is handicapped by a lack of coking coal of high quality. The iron ore mined, nearly all of which is exported to the United States, averaged 1,383,000 metric tons during the 1935-1939 period but dropped about 40 per cent below that figure during World War II because of shortage of shipping facilities. Since 1946 the prewar output has been exceeded.

Brazil is credited with the largest reserve of high-grade ore in South America and one of the largest in the world. As high as three billion tons of ore ranging from 63 to 68 per cent metallic iron have been estimated to be located at Itabira in the state of Minas Geraes, about two hundred miles west of Vitoria. The coal needed for the smelting operations is found in southern Brazil, and therefore it is planned to ship the ore southward by water route to meet the coal at Volta Redonda, between Rio de Janeiro and São Paulo, where a large iron and steel plant is designed to meet a part of Brazil's needs.[1] Because of the transportation costs of bringing the ore and the coal by land and sea to Volta Redonda, and then the metal as iron and steel to the factory centers, it seems improbable that the young iron and steel industry can compete successfully with the finished products obtainable from the efficient and established sources in Europe and North America. The probabilities therefore point to increasing exports of Brazilian iron ore to the markets in Europe and the United States. There is propaganda afoot in Brazil to attempt to develop a large iron and steel industry under the protective wing of a duty on imports, which of course means support of the industry at public expense, disguised as a tariff. The degree of success this movement may have in winning support is an open question.

Discoveries of huge deposits of high-grade iron ore have been reported recently from Venezuela, and it is said that negotiations for exploitation are in progress. In Venezuela as in Brazil the difficulty to be faced in establishing a successful steel industry is that of lack of coking coal. If coking coal is not found within economic reach locally, most of the iron ore will find its markets abroad, perhaps chiefly in eastern United States.

Africa. Three areas in Africa are gaining prominence for their potentialities for large-scale ore production in the future: North Africa, Rhodesia, and South Africa (see Illus. p. 432). In northern Africa, Tunisia, Algeria, and Spanish and French Morocco reported a total output of more than 2,750,000 metric tons of ore in 1946. This area is in position to furnish large amounts of ore for reduction to iron in the expanding industrial centers of western Europe, and therefore a continuing upward trend in production may be anticipated.

In central Africa, extensive bodies of low-grade ore with a metallic content of 25 to 30 per cent have been reported. The comparatively low metallic content and the railway haulage involved in marketing appear to be deterrent factors against early development to any large extent. In South Africa, on the other hand, the Transvaal ores are high grade, 50 to 60 per cent metallic content, and the growing markets are near at hand (see Illus. p. 432). The total reserves in the Union of South Africa have been estimated to exceed 10 billion tons, but the high-grade ores constitute but a minor fraction of the total, perhaps about 122 million tons. The average annual output during the war period (1941-1945) reached 781,000 metric tons, and later reports indicate larger annual production since 1945. A moderately rising trend may be expected to continue during the foreseeable future.

Asia. Asia's ore resources are widely scattered and of huge magnitude but, on the basis of quantities produced, must be ranked as of secondary rather than primary industrial importance. India, Japan, and North China (including Manchuria) all have long had recognition as important producers of ore and of pig iron, but only Japan made important progress in steel manufactures. Since 1930, however, the Soviet Union in Asia has made great advances in all phases of the iron and steel industries.

Japan is weak in iron ore and in coking coal. Under the necessity of war she expanded her ore output to more than four times the normal production of peacetime, and furthermore, she drew upon the ore resources of North China, the Malay States, and the Philippines, and thus was able for a time to meet the excessive demands of the military program. When she lost control of the overseas sources her doom was sealed; the final result was hastened but not created by the atomic bomb. In peacetime, Japan can, and undoubtedly will, maintain a strong industrial position provided she can have available the iron ore and the coking coal from the continent. Costs of water transport are low, and the Japanese can provide the skill and the labor essential for success.

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[1] The rolling mill at Volta Redonda began operations Oct. 12, 1946. In the first year of full operation, 1947, the output was 68,631 tons of pig iron, 22,243 tons of heavy melting scrap, and 85,451 tons of iron and steel products.

Large iron-ore deposits have been reported from Mindanao in the Philippine Islands, and in 1940 output reached the sizable figure of 1,248,000 metric tons. The ore is reported to be of high quality, and annual output can undoubtedly be increased greatly over the 1940 figure if market outlets become available.

India has large bodies of high-grade, low-phosphorous ore containing approximately 60 to 62 per cent metallic iron. The Bihar-Orissa mines are about a hundred miles west of Calcutta where outcrops are at low angles and are easily mined (see Illus. p. 432). Kali Mati, 45 miles to the north, is the center of the iron industry of India, where, because of adequate supplies of coking coal near by, the lowest-cost pig iron in the Orient can be produced, a factor largely responsible for the rapidly increasing industrialism of northern India. In the past, much of the pig iron has been exported to Japan, Germany, the United Kingdom, and some even to the United States.

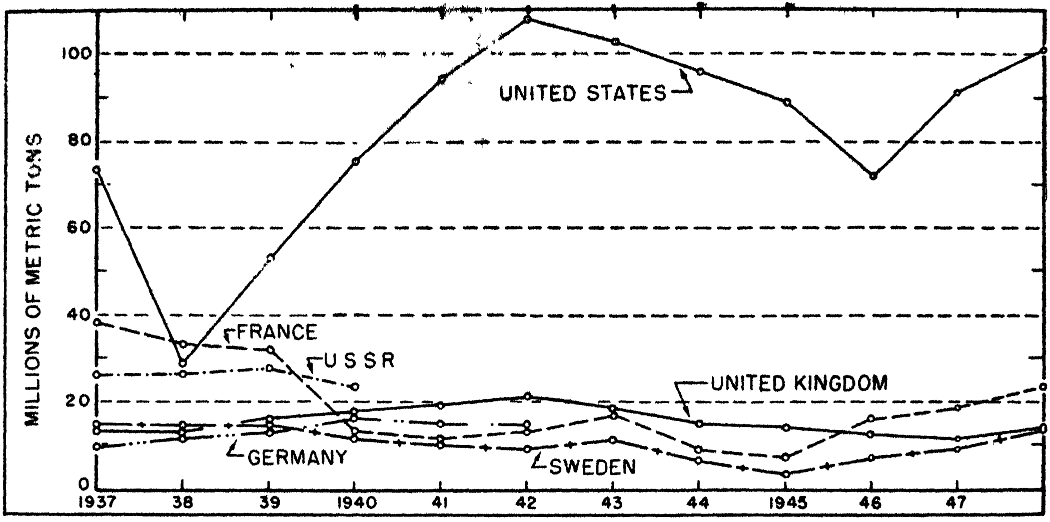
The iron ores of China appear to be rather small bodies widely scattered, mostly south of the Yangtze River near Hankow and in northern China. Under the impact of war, annual production exceeded 15 million tons during the early war years, 1942 and 1943, but it appears doubtful that this quantity will be reached in the near future, even if and when internal strife ends. The deposits in Manchuria are reported to be extensive but of low grade.

AUSTRALIA AND OCEANIA. Australia and some of the islands of Oceania are reported to have important reserves of iron ore, although they may not constitute a high percentage of the world total. Ores have been mined commercially on a limited scale in five of the major provinces. The principal production has come from South Australia (see page 432), with New South Wales a poor second. During the war period, 1941-1945, South Australia alone averaged 2,051,000 metric tons annually, which was 93.8 per cent of the total output of the Dominion. The iron and steel industry of Australia is designed chiefly to serve local needs. The output of pig iron during the war period averaged 1,365,000 metric tons, but peacetime production will probably fall below 1,000,000 tons per year. While both coal and iron ore are available and of high quality, industrial development will be slow because of lack of extensive markets. The general curve promises to continue gently upward as the general trade territory develops.

New Zealand appears to have ample reserves of ore to meet her needs, and in recent years expansion of smelters and steel plants has been rapid. The output of iron ore increased from 1.4 million tons in 1940 to 7.5 million tons in 1946.

EUROPE. During the years immediately preceding World War II, five major iron-ore regions produced about three-fourths of the world total: (1) the Lake Superior region, (2) the Lorraine region of France, (3) the Krivoi Rog deposits of the Soviet Union, (4) the Kiruna district of northern Sweden, and (5) the Birmingham district of Alabama, in the order named. It should be noted that, of these five districts, two are in the United States and three are in Europe (see Illus. p. 432). It is worthy of emphasis that output of iron ore, or of any other irreplaceable resource, is not in itself a measure of the quantity available for production; it is, however, a good index of the industrial development of the states or districts indicated.

GREAT BRITAIN. The four districts of eastern England that still rate as highly important in output of iron ore are the Northampton, Leicester, Lincoln, and Cleveland Hills districts. These, and some of lesser importance, are within low-cost reach of the excellent coal of Yorkshire and southern Wales. In the central lowland of Scotland similar conditions prevail; and thus in the nineteenth century the industrial supremacy of the British Isles became a recognized fact. However, with continued extraction it was found that the quality of the ore became lower and that mixing the domestic low-grade ores with richer imported ore became economically desirable. The first peak of England's output of domestic ore was reached in 1882, when 18,328,000 tons were produced. This peak was followed by a slow but irregular decline during the following decades, a low point being reached in 1932 with a total output of only 7,445,000 metric tons. Some recovery followed, but it was generally believed that never again would Britain equal the peak of 1882. Then came World War II with its threat of total destruction of the home plants so necessary for the war effort, and Britain feverishly reversed a policy of long standing and gave all possible aid and encouragement to the establishment of furnaces, steel plants, and factories in Canada, Australia, New Zealand, South Africa, and even India, while at the same time labor in the home island did what had been believed impossible—turned out iron ore from British mines in 1941 to 1943 that exceeded the former peak of 1882 by nearly two million tons per year (see graph below).



Annual production of iron ore for each of the principal producing countries of the world. Note the continuously predominant position of the United States. No recent data available for the Soviet Union or Germany. How does one account for the sharp upturn of American increase output following 1946?

The result of the war and the shift in policy necessitated thereby lessened Britain's reserve of ore, a large reserve still, and it set up competition for Britain in the markets of the world outside the Dominions. At the same time it induced the Dominions to become more nearly self-sufficient and therefore less dependent than formerly upon imports of the many iron and steel products and the numerous indirect commodities associated with iron and steel machinery. The net effect is, of course, a serious loss in foreign markets so needed to maintain Britain's economy. It will demand huge efforts and self-sacrifice on the part of the British to re-establish their prominence in the industrial world. The downward trend in the output of ore will undoubtedly be resumed, and the job of manufacturing and marketing the machinery and other durable steel goods in the highly competitive world ahead presents to labor and management alike a problem of the first magnitude.

France. During the decade preceding

World War II, the Lorraine district of France ranked second to the Lake Superior region of the United States in yearly output of iron ore. During the prewar period, 1935-1938, the yearly average output of ore in France was slightly above 34 million metric tons (see Illus. pp. 432 and 435), about 95 per cent coming from the Lorraine deposits. The Lorraine ores are not rich in metallic content, averaging only about 33 per cent iron, but their occurrence with limestone renders them readily smelted at relatively low cost. As a whole, the Lorraine Basin is credited with being the largest single ore body reserve in Europe.

The proximity of the Lorraine ores to the coking coal resources of northeast France and the Ruhr, and the coal of the Saar Basin, tends naturally to favor development of iron and steel works both in France and in Germany. The seizure of Lorraine by the Germans at the close of the Franco-Prussian War of 1870 enabled Germany to industrialize at a highly accelerated rate, as the rapid rise of the Rhineland-Westphalian so eloquently testified. In 1913 that area, including the Ruhr, was the greatest steelmaking district in continental Europe. Regaining the Lorraine Basin in 1918 enabled France to become the greatest ore-exporting country in the world, and it also served to aid France in building an iron and steel industry of large capacity within her own country. The cargo-carrying trains and vessels taking ore to the Saar and to the Ruhr could readily bring the needed coking coal *from* the Ruhr and the Saar to serve the needs of the furnaces and steel plants of the Lorraine district of France. In the absence of economic restrictions, such as tariffs and quotas, political boundaries need not be, in fact they should not be, barriers to normal exchange of commodities and the establishment of industry.

What of the present and the near future trend of the iron and steel industries of France? No definite answer can yet be given. The trend will depend largely on the manner in which the social and political questions will be handled. France has the reserves of ore, and ready markets will be available in Britain and Belgium, and also in Germany, provided that country will be encouraged to develop industries on a basis of enduring peace. Since supplies of coal are near at hand within her own borders and in Belgium and Germany, France can buy coal in the kind and quantity needed, provided the natural markets for French ore and other products are restored to normal activity. The greatest of such markets are in England and Germany.

THE GERMAN SITUATION. Based on the boundaries that were recognized prior to the outbreak of World War II, Germany was rich in steam and coking coal in the northwest, the well-known Ruhr district, and also in the southeast in Upper Silesia. The most important iron-ore resources were in the west within about 150 miles of the Ruhr coal (see Illus. pp. 366 and 432). The ores are low grade, with average metallic content of less than 30 per cent, and they are difficult to reduce to pig iron. With her abundant stores of coking coal and readily available ocean shipping facilities, Germany could easily obtain high-grade ore from Sweden to supplement her own low-grade supply. Furthermore, she was in position to import iron ore from France and to provide coal as return cargo, thus, through exchange, reducing shipping expenses to a minimum. As a result of this situation Germany became a heavy importer of ore and exporter of coal during the decade of the 1930's, at the same time building up her steelmaking capacity to distinct leadership among European countries. During the years immediately preceding World War II, Germany produced about 8 million tons of ore yearly, about 16 million tons of pig iron, and more than 20 million tons of steel. The large output of pig iron and steel was made possible by imports of iron ore largely from France and Sweden and by the scrap iron available within Germany, supplemented by imports from other European countries.

The industrial progress made by Germany was made possible by her fuel and power resources. Full employment resulted, and a wave of prosperity became realized which unfortunately was but temporary because the goods made under those conditions were too largely designed and used for purposes of destruction; had they been designed for production rather than destruction, the results would have been enrichment for Germany and the whole world.

What of the future? The steam and coking coals are still present in Silesia and the Ruhr in large, easily mined quantities. Silesia has passed out of German control, but the Ruhr remains. Huge stores of high-grade ores can still be obtained by water routes from Sweden, and the French ores are no farther removed from the Ruhr than was the case before the war. The physical conditions remain unchanged, but not so the political conditions. If the resources are used constructively, the results will be beneficial to all, former allies and enemies alike; if they are not so used, the results will likewise be negative. Lack of use will mean lack of production, and lack of production leads to poverty and misery.

Belgium and Luxembourg. Lying between the great ore deposits of the Lorraine Basin and the coal beds of the Ruhr are the two small but industrially important countries of Belgium and Luxembourg. The former has coal but little iron ore, whereas the latter has much ore but little coal. Both are within easy reach of additional stores of both coal and ore as well as of transportation facilities to foreign markets. During the prewar period, 1935-1938, Luxembourg's average annual output of iron ore was 5,484,000 metric tons, which gave to that country high rank in proportion to size and area. The war and postwar periods have been characterized by reduced output of both ore and pig iron, but the trend may be expected to be upward until the prewar output has been reached or exceeded.

Belgium's ore output is small but her imports are large and serve as a basis for a very active iron and steel industry. The stores of coking coal, ore supplies readily obtainable, well-developed seaports, and an industrious population have enabled Belgium to become one of the foremost iron and steel manufacturing countries in the world in proportion to size. The extent to which the Belgian iron and steel industries are dependent upon foreign ores may be inferred by the fact that from 1934 to 1938 an average of only 183,000 metric tons of iron ore was mined per year while the annual production of pig iron was 3 million tons per year. Since the domestic market is small, the iron and steel industries have been developed largely on the basis of export trade. The iron and steel exports ordinarily have amounted to 60 or 70 per cent of the total output, and foreign sales at about this ratio are necessary if the Belgian mills and men are to be gainfully employed.

Sweden. Sweden has long been famous for the quality of her steel manufactures, a fame achieved long before she became known for her large ore reserves. The early industries were small-scale affairs, using the easily smelted carbonate ores of central Sweden with charcoal for smelting the ore to metal. The carbon steel resulting from these resources and the skillful processes developed by the early Swedish workers, produced high-grade cutlery, particularly swords, which gave rise to a reputation for quality which endures even to this day.

Sweden now is internationally known for the great reserves of magnetic iron ore in the far north of the country in the Kirunavaara and Luossovaara districts beyond the Arctic Circle (see Illus. p. 432). This ore averages above 60 per cent iron. During the prewar period, 1935-1939, the total annual production of Swedish ore, mostly from the Kiruna district, averaged 12,370,000 metric tons. During the war years the average output dropped to 8,452,000 metric tions (see Illus. p. 435). Under peacetime conditions, the annual production of the Swedish mines may be expected to range between 10 and 14 million tons, of which about 80 per cent will be exported, Germany and England being the principal customers and lesser amounts being shipped to Poland and Belgium and some to the United States.

The Swedish iron and steel industry is

handicapped by the lack of coking coal. This lack is overcome partially by the availability of coal by water transportation from Germany and England, supplemented by charcoal from the extensive forests which is still being used to some extent in the manufacture of Swedish steel. On the whole, marked success has been achieved through emphasis upon skill of workmanship. The industries are expanding and prosperous because of specialized production wherein skill in manufacture is the first essential, as in fine cutlery, ball and roller bearings, and high-grade tool steel. The future of the Swedish iron and steel industries seems therefore to be securely on the up-trend because foreign markets are expanding for the ore as well as for the finished products, which are rated high upon the basis of quality rather than merely upon quantity.

Poland and Czechoslovakia. Poland and Czechoslovakia both participate, presently at least, in the coal and ore resources of Silesia, formerly chiefly under German control. The resources within Poland's prewar borders include some low-grade iron ores in the western part of the country, as well as in the Silesian area of the southwest. They also include steam coal, but there is a lack of high-quality coking coal. In order to develop a strong iron and steel industry it seems, therefore, that Poland will find it necessary to import high-grade ore to supplement her own low-grade ores (25 to 35 per cent metal) as well as to import coke or coking coal essential in reducing ore to pig iron and in converting pig iron into steel.

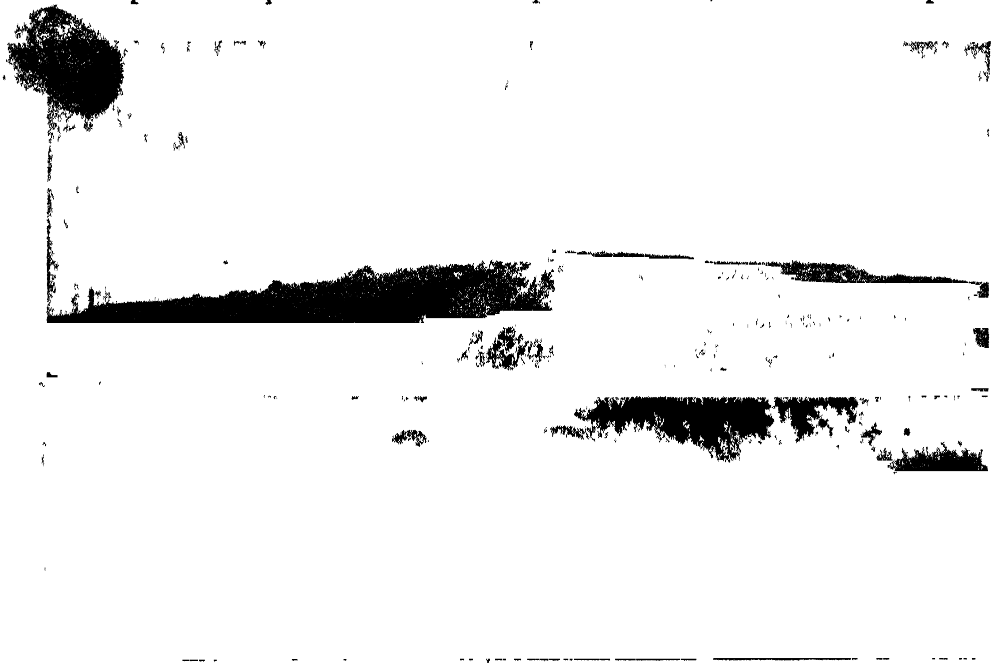


Photo by N A B

One of the large iron ore mines at Kirunavaara, Sweden. The ore mined is a high-grade magnetite and the open-cut method of mining is used The ore body lies between the footwall at right and roofwall at left, at an angle dipping toward the left

Czechoslovakia is more fortunate because she has within her own borders in Bohemia the necessary natural resources—ore, coking coal, and limestone—for the establishment of a successful iron and steel industry. Furthermore, she has already established high reputation for the quality of her steel goods, precision instruments, and armaments. During the pre-invasion period, 1935-1937, Czechoslovakia produced an average yearly output of 1,219,000 metric tons of ore and 1,172,000 metric tons of pig iron. If the political uncertainties can be peaceably and satisfactorily resolved, the trend of the iron and steel industries may be expected to continue upward. It is to be hoped that the success of the Czechoslovakian nation may be symbolized by constructive progress in rebuilding the losses caused by war, rather than by creating instruments and armaments whereby further destruction might become the result.

THE SOVIET UNION—EUROPEAN AND ASIATIC. In this discussion we prefer to use the expression *Soviet Union* to designate the vast area officially termed the Union of Socialist Soviet Republics and to limit the term Russia to the portion of the Soviet Union which is ordinarily accepted as part of Europe.

Russia has long been recognized as one of the leading European countries in the output of iron ore. In 1913 Russia mined 9,210,000 tons of ore and smelted more than four million tons of pig iron. Then, because of the disruptive conditions of World War I, the iron and steel industries were depressed almost to extinction and postwar recovery was exceedingly slow for the ensuing decade. More recently, however, progress has been exceptionally rapid. During 1935-1938 the average annual output of ore in the Soviet Union was reported as 26,941,000 metric tons, and during the same years an average smelter output of 14,410,000 metric tons of pig iron was reported (see Illus. p. 435). No official statistics have been released since 1942, but it is common knowledge that at the height of the German invasion the output of ore and of iron and steel products was seriously reduced. The rate of recovery since 1945 continues to be a carefully guarded secret for reasons difficult to understand, but estimates made by those who have had some glimpses behind the closely drawn iron curtain indicate substantial progress. It is possible that the Soviet Union has attained and may have exceeded the position reached prior to World War II. It seems certain that the Soviet Union now ranks second only to the United States in the several phases of the iron and steel industries.

That the iron ore resources of the Soviet Union are large and scattered is well known (see Illus. p. 432). High-grade ores, averaging 45 to 55 per cent iron, are plentiful. One of the best iron districts of Europe is in south Ukraine and is known as the Krivoi Rog deposit. This region during the prewar years produced about 60 per cent of Russia's total ore output. The Krivoi Rog ore and the Donetz Basin coal are within easy reach of each other, and thus two-way cargo transportation has led to iron and steel plants in both areas. The extent of the Krivoi Rog reserves is not definitely known, but estimates place them at not less than 2 billion tons of high-grade ore.

The southern Urals (see Illus. p. 432) is the second in rank among the Russian areas of exploitation, an area that has been producing about 25 per cent of the ore output of the nation. One of the foremost sources is Mount Magnitnaya, which provides much of the ore for the steel center at near-by Magnitogorsk. Since suitable coal must be hauled long distances, first impressions tend to question the economic soundness of establishing blast furnaces, steel mills, and by-products coke plants in connection with the ore mines. On the other hand, it is reported that steel plants have also been established far to the east in the Kuznetsk Basin and in other areas near-by where high-grade coking coal is available. Although coking coal and iron ore are separated by distances exceeding a thousand miles by rail, two-way haulage of coal and ore, with little if any empty haulage, will reduce materially the costs ordinarily assumed to be incidental to carrying coal to iron ore.

Other ore centers are scattered over much of the Soviet Union. The total reserves indicated are huge; estimates can only be guesses, but it seems safe to assert that no country is better supplied with potential reserves for long-time development. The distances separating coal and ore and the remoteness from the great industrial centers of the present constitute barriers to be overcome in a competitive world.

THE MEDITERRANEAN COUNTRIES. Northern Africa has long been known for its abundance of iron ores, and mining for export has been accepted as common practice for several decades (see Illus. p. 432). On the European side, Spain has likewise provided ore for the markets of Britain and Germany but has not developed a great domestic iron and steel industry, this in the face of a reputation attained long ago for high-quality cutlery steel. Spanish steel production, ordinarily less than a million tons a year, uses imported scrap and domestic pig iron in nearly equal amounts.

The unmined iron ore reserves of Italy are estimated at about 33 million tons, which by beneficiation can be raised to 50 per cent metallic content; however, costs are high. The output during 1935-1939 averaged 845,000 tons yearly, but it seems improbable that this figure can be equaled under competitive peacetime conditions. Coal resources, particularly those of coking quality, are so limited as to be insufficient to sustain a steel industry commensurate with the needs of the country. The hydroelectric power available can be used in the manufacture of high-quality and high-priced alloy steels but is too expensive for the making of ordinary structural steels.

Summary of the world situation. From a material point of view, the present has frequently been called by some the Power Age and by others the Age of Steel. Both appear to be right, because both the preparation of steel and the use of steel involve power. Each demands the other, for steel is truly the heart of the modern industrial system. Low-cost steel is essential to commercial competition. For the foreseeable future the countries most favorably situated for production of cheap iron and steel will probably continue their industrial prominence and, through the success thus achieved, furnish the political leadership of the world. The principal centers for output of low-cost iron and steel are the United States, the Belgium-Ruhr-Lorraine Basin area supplemented by Scandinavia and Spain, the Ukraine and southern Ural area, and northern India. From these centers we may expect industrial leadership to emanate with its attendant effects on employment and general prosperity, and even on international politics.

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Chapter Twenty-five

INDUSTRIAL IMPORTANCE OF THE FERROALLOY METALS

For centuries iron manufactures were based chiefly on carbon content and quick temperature changes for hardening and toughening into the product that early became known as steel. Charcoal was the source of carbon, and inasmuch as the charcoal contained no deleterious impurities, little difficulty was caused by introducing impurities not inherent in the ore itself. The quality of the output, whether it was known as iron or steel, depended largely upon the purity of the ore and the skill in managing the smelting processes so as to acquire as much hardness and toughness as was desired for particular uses, the most important of which was a sharp cutting edge. Under these conditions, the carbonate ore being generally quite free of impurities, especially sulphur, was readily made into high-grade qualities of iron and steel. In this regard England and Sweden were favored with available siderite ores and, before the forests were severely cut, also with an abundance of charcoal; to a lesser extent Spain was favored by similar conditions. The steels from these countries acquired lasting reputation, particularly in the field of cutlery, a reputation that still endures and is even now a business asset.

Evolution of modern steel manufacture. With an increasing demand for iron and steel and a decreasing supply of charcoal as a source of carbon, it was natural that England should take the lead in changing from charcoal to coal. The change began there in the eighteenth century with the use of the hardest coals obtainable, those containing a high percentage of fixed carbon and having the quality of fusing into coke when heated. For some time the change from charcoal to coke was judged by many to result necessarily in a product inferior to the old-fashioned carbon steel made from charcoal. Gradually, however, difficulties were overcome, and steelmaking on a modern basis entered its period of great development about the middle of the nineteenth century.

The essential processes involved in making steel, whether charcoal, coal, or coke is used as the reducing agent, are: (1) The ore must be smelted to metal by eliminating most of the impurities, a reduction process, the resulting metal being referred to as *pig iron.* Pig iron, however, ordinarily contains from 3 to 5 per cent carbon as well as varying amounts of other impurities. (2) The metal must be purified, a process that involves oxidation of the impurities, thus leaving nearly pure metallic iron. (3) The adjustment of the composition of metallic iron is made through introduction of fixed proportions of desirable hardening materials; the resulting product is steel.

These three essential procedures may be accomplished in various ways. In 1856 Sir Henry Bessemer devised a vessel with a sandstone lining in which the molten iron could have air blown through it from the bottom. The heat given off by the molten iron would raise the temperature of the air introduced to the point where it would oxidize such impurities as carbon, manganese, or silicon. This operation, known as the Bessemer process, was improved in 1878 by the use of a limestone lining which made its use practical for ores of higher phosphorus content than was originally possible with the Bessemer furnace.

In 1857-1858, however, Sir William Siemens devised the open-hearth furnace wherein the processes of converting pig iron to steel could be carried on at a slower rate and could be more carefully watched for progress than was possible with the Bessemer furnace. At first the open-hearth furnace used pig iron only, but it was soon learned that scrap could be added. This constituted a great improvement because in the modern steel industry scrap metal accounts for 40 to 60 per cent of the charge placed into the iron and steel furnaces.

Near the close of the nineteenth century an electric furnace was devised and was first used in Italy, Sweden, and France, where cheap hydroelectricity was available. The furnace is a rounded steel shell lined with basic or acid heat-resistant bricks known as refractory material. Temperatures reaching 3,000°F. are obtained by passing electric current through electrodes which are suspended from the upper section of the furnace. The process is more expensive than either the Bessemer or the open-hearth process, but it is capable of a higher degree of precision for finished products and therefore is prized where a uniform, high-quality steel is the first consideration. In the United States during the period 1942-1946, 89.5 per cent of the steel produced was provided by the open-hearth method, 5.8 per cent by the Bessemer method, and 4.6 per cent by the electric furnace method.

Alloy steels. All steel is made by following the essential principles and processes outlined above: reduction of ore to metal, purification of the charge of pig iron and scrap iron, and adjustment of the composition of the metal to meet desired needs. The latter point refers to the content and structure of the finished product; these are made possible by temperature control, together with the addition of such metals in closely measured amounts as are necessary to produce steel of the quality desired. Virtually all kinds of steel contain carbon in varying amounts, and many kinds of steel have had some other hardening elements added in small quantities in order to meet definite requirements for specific uses. The other elements—known as alloy metals—which are most commonly used include manganese, molybdenum, nickel, chromium, vanadium, tungsten, cobalt, and some others of local and lesser importance. Steels that include at least 1.65 per cent manganese and any of the other nonferrous metals are known as *alloy steels.*

During the 1942-1946 period, the average annual production of the alloy steels ranged from 6 to 13 million tons and constituted 12.8 per cent of the total steel output of the United States.

Importance of scrap iron and scrap steel. Raw material for blast furnaces and steel plants includes scrap iron as well as pig iron. About one-third of the world's steel is made from scrap; in some countries that are weak in iron ore the furnaces depend largely upon scrap, for example, Argentina, Japan, and some of the Mediterranean countries. In the United States ordinarily scrap is the source of 30 to 50 per cent of the output of steel. In 1942-1946 the average annual consumption of scrap iron and steel was 57,800,000 short tons and of pig iron, 55 million short tons. Of the combined total, scrap accounted for 51 per cent and pig iron, 49 per cent. While scrap is gathered from every state, Pennsylvania, Ohio, and Indiana usually lead, with a combined consumption of 60 per cent of the nation's total. The open-hearth steel furnaces are by far the largest consumers of ferrous scrap and pig iron, and their proportional percentages hold fairly steady at around 65 to 70 per cent of the total, with electric furnaces using 7 to 10 per cent and Bessemer converters using comparatively small quantities of scrap.

Scrap has long been an important source of steel, but its use in blast furnaces has become prominent in the United States only within the past two or three decades. It serves to stabilize the price of pig iron and thus, indirectly, the price of ore. When scarcity of pig iron threatens, the price rises and with it the price of scrap. In the early postwar period, 1945-1948, the rising prices put dollar values into iron scrap heaps over the nation and thus gave an economic incentive for collection. The humble driver of the junk-collecting truck became, in a sense, a member of the metallic aristocracy. The re-use of the metallic resources implied in the term *scrap iron* is a conservation measure of great significance to the nation that makes full use of it.

The alloy metals of major importance. With recognition of the raw materials vital to the iron and steel industry—ore, coal and coke, and fluxing material (usually limestone)—and the essential procedures indicated by blast furnaces, steel converters, and rolling mills, the grosser materials and processes have been outlined as fully as seemed warranted within the scope of this study. We still need to make clear why steels differ in specific quality and how they are truly "tailor made" to meet certain needs, such as are typified by spring steel, tool steel, high temperature steel, and so forth. For that explanation we must turn to the alloy metals, which can be used in varying percentages, singly or in combination, to produce such a variety of results as to bewilder the imagination of the novice; the details lie in the complex field of metallurgy wherein the scientific advances during the past quarter of a century have indeed been astounding. While details do not come within our province, the broader effects of the important alloys are of such industrial and economic significance that economic geography would be amiss if it gave no recognition to the alloy metals which produce them.

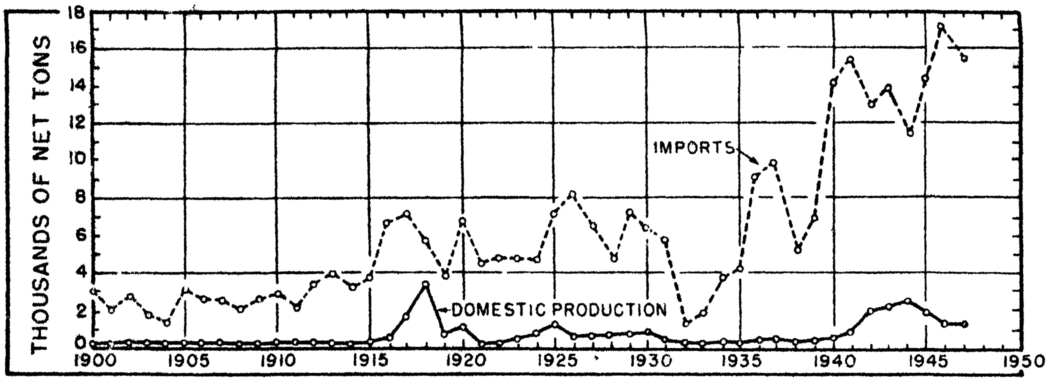
Manganese

Manganese is essential to the production of good-quality steel. Some steels that contain far more of this metal than do others are therefore known as *manganese steel.* In the making of ordinary steel small amounts of manganese serve to remove the oxides formed by melting the iron preparatory to its purification before making it into steel. An average of fourteen pounds of manganese is used for every ton of steel that is made. In addition to its function of removing impurities such as oxides and sulphur compounds, manganese adds many desirable qualities to steel. Although it serves a number of other uses, particularly in the chemical industries, 95 per cent of the production is used in the metallurgical industries.

Manganese is added to steel either as *ferromanganese* or as *spiegeleisen.* The former is an alloy of iron that contains about 80 per cent manganese; 80 to 90 per cent of all the manganese used in the manufacture of steel is added in this form. Spiegeleisen is an iron-manganese alloy that in the standard grade contains 20 per cent manganese. Because of its greater efficiency as used in the steelmaking processes, ferromanganese is preferred over spiegeleisen by steel manufacturers, even though the cost per unit of the metal is decidedly greater.

Manganese steel is tough, hard, and resistant to abrasion and corrosion. Steel rails made of manganese steel are reported to be five to six times as durable as those made of ordinary carbon steel. Manganese steel is preferred for heavy-duty machinery, such as that used in mining, rock crushing, milling, roadworking, and dredging. It is also used in certain types of tool steel, especially where the tools are to be subject to severe abrasion or to hard impacts. Manganese steel is used extensively in the electrical industries because, if its content of manganese is as high as 11 to 14 per cent, it can readily be made nonmagnetic and so becomes a much poorer conductor of heat and electricity than ordinary steel.

Manganese is similar to iron in its occurrence and many iron ores contain it in considerable amounts. Ores containing from 5 to 10 per cent manganese produce a high-manganese pig iron that is much in demand.



Manganese. Production and imports, United States, annually since 1900. Note the effects upon domestic production during the war years, 1915-1918 and 1940-1945. How account for the dip in imports, 1930-1935?

Manganese ores in the United States. Although two thousand or more occurrences of manganese have been reported in the United States, only a few appear to have any commercial possibilities. At Butte, Montana, large veins of manganese carbonate, barren of copper, are associated with the veins that contain copper ore. During periods of war emergency this source is claimed to be capable of producing large quantities of manganese, but at costs too high for successful competition during peacetimes. The reserves have been estimated at several million tons of carbonate ore. At Phillipsburg, Montana, manganese ore in moderate quantities has been reported in limestone. Goddard, in *U.S.G.S. Bulletin 922G*, estimated that there were 375,000 tons of ore containing 30 to 45 per cent manganese and at least 125,000 tons of lower-grade ore.

Manganese ores in small quantities have been reported in South Dakota, Arkansas, Virginia, Tennessee, and Georgia. In the southwest, ores have been discovered and some production has been reported from New Mexico, Nevada, and southeastern California. In connection with the iron ores of the Lake Superior district, manganiferous ores in substantial amounts occur in the Cuyuna Range in Minnesota and in the Gogebic Range of Michigan, but these ores, although of value for manganiferous pig iron, are not suitable as sources for metallic manganese.

On the whole, therefore, the United States is sadly lacking in known reserves of manganese so essential in the steel industry and apparently must continue to be dependent upon foreign sources to supply most of its needs (see Illus. above).

Important foreign sources of manganese. The Soviet Union contains the greatest known reserves and has in the past provided the largest production of any nation in the world; in 1940 the Soviet Union provided more than 50 per cent of the world supply. South of the Caucasus Mountains in the Republic of Georgia, a bed of manganese oxides has been reported to underlie 55 square miles of area. The bed is 4½ to

7½ feet thick and contains layers of nearly pure manganese dioxide (MnO_2) that aggregate three to four feet in thickness. This one deposit has in the past years supplied nearly half of the world's manganese. Another deposit of international fame is in production north of the Black Sea. The bed is reported to be up to 5 feet thick and has been proved over an area of 7 to 8 square miles. Since still other deposits have been proved, it appears certain that the Soviet Union is endowed with huge reserves of manganese ore.

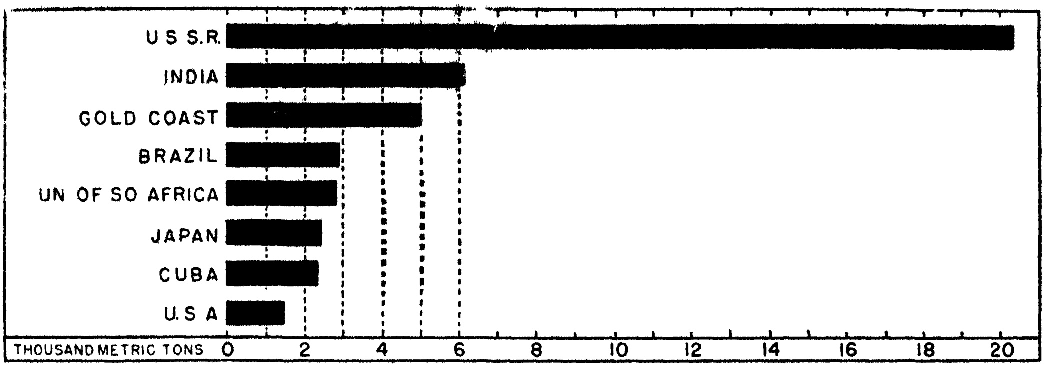
In Europe, outside of Russia numerous small deposits of manganese ore have been found in most of the countries, as [illegible] is been found in the United States, but large-scale production has not proved possible even with the financial inducements that have been extended by the several governments.

Asia appears to be favored with manganese ore of economic importance in India and in the Philippine Islands. From Baroda on the West Coast across central India nearly to Calcutta a manganese belt has been reported for a distance of about 700 miles. In this area a number of ore bodies have been found, but the chief center of production is reported from the western portion. In the Philippine Islands recent explorations have revealed large deposits of manganese ore which appear to give assurance of contributing substantially to the world's supply in the future.

A number of small manganese ore bodies have been reported on the Japanese islands, but no large reserves have been discovered. Hokkaido and Honshu have contributed the major part of the output in the past, the best-known center being near Kyoto.

In Africa are two centers of exploitation of manganese ore, one in the Gold Coast and one in the Union of South Africa. The former is in the hands of American capital interests, while in the latter British capital is in charge. Reserves are reported to be substantial in each area, but the percentage of metal is rather low and therefore high prices for output are necessary for economic success (see Illus. above).

In the Western Hemisphere Cuba and Brazil have recently been the principal areas of exportation, but the known reserves of the former are reported nearly exhausted. Chile was early a relatively important exporter of manganese ore mined near Coquimbo. Exports of 26,628 tons were reported in 1947, of which 92 per cent were shipped to the United States. In northern Cuba, fairly extensive deposits have been exploited for many years by American capital interests. Brazil promises to become a source of production of high importance to the western world. Reserves of high-grade manganese ore have been esti-



Manganese. Graphic illustration of average annual production of principal countries, 1940-1945. Data for U S S. R based on estimates presumably quite reliable.

mated to exceed 10 million tons in the state of Minas Geraes, where Ouro Preto is the principal mining center. High-grade manganese ores are also reported to have been found in Mato Grosso to the west.

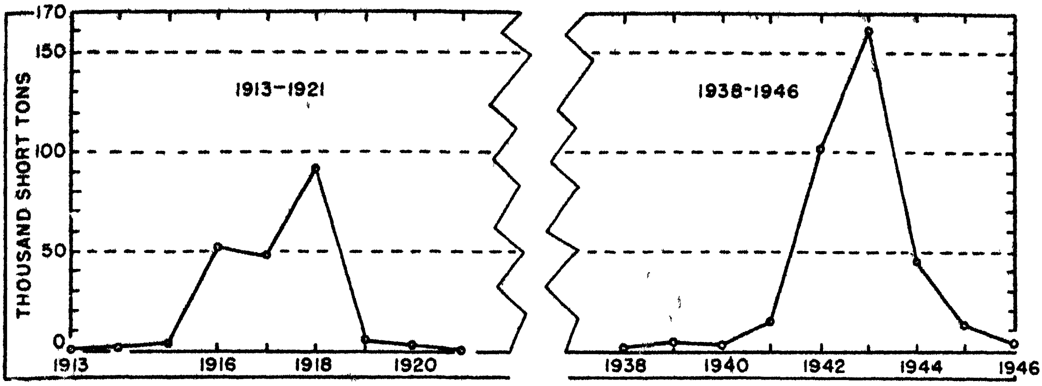
Summary. The principal sources for manganese for the world's steel industry have been found to be the Soviet Union, India, the Philippine Islands, Africa, Cuba, and Brazil (see Illus. p. 445). Of these, the Soviet Union is the only important steel making country that has manganese within its borders sufficient to meet its own demands. The other large steel-making countries must depend upon imports. These include particularly the United States, the United Kingdom, Germany, Japan, France, and Belgium. The United States, during the prewar period, imported about 750,000 tons of manganese ore per year, but during the war years imports of ore were nearly doubled, with India and the Gold Coast ranking as the foremost sources. The world production of manganese since 1940 has averaged 5 to 6 million tons annually, of which the Soviet Union has supplied 45 to 60 per cent, India 20 per cent, Africa 2.5 per cent, and Brazil 20 to 25 per cent. The political control of the exploitation of manganese ore, indispensable to the steel industry, is almost entirely in the hands of the Americans, the British, and the Russians.

Chromium

Metallic chromium is bluish white in color. It possesses high metallic luster and has a hardness of 9, nearly as hard as diamond, which is rated 10 on the scale. The properties of chromium render it valuable for many uses, particularly as an alloy. The ore from which most chromium is derived is chromite ($FeO \cdot Cr_2O_3$), with a theoretical composition of 68 per cent of chromium sesquioxide (Cr_2O_3). Chromite is dark in color, varying from black to yellowish red, and it is infusible. The world's production of chromite is used for refractory purposes, in the chemical industries, and in the metallurgical industries. As a refractory material it is used as lining of furnaces, where resistance to fusion under high temperatures is of paramount importance. In the metallurgical industries chromium is an essential alloying material for high-speed steel, stainless steel, and many of the engineering steels. In the making of steel, chromium imparts strength, toughness, hardness, resistance to corrosion, and high electrical resistance. As a result, chrome steels have made possible certain industrial developments that would not have been possible otherwise. Hard steels are used in the automotive industry, in the manufacture of airplanes, high-speed tools, armor plate, engine parts, and various light and heavy equipment. One of the most commonplace uses of metallic chromium is in plating other metals.

In the United States, the first well-established output came from the Reed Mine in Maryland in 1827. Thereafter this country led the world in chromite production until 1860, when Turkey took the lead. This was followed by Russia in the lead from 1897 to 1902. Since then, first place has alternated among the United States, India, New Caledonia, Cuba, and southern Rhodesia. While statistics are incomplete, it appears that the Soviet Union regained first place in production about 1935 and probably still holds it.

Chromite-bearing rocks are known to occur in the mountainous areas of North Carolina, Maryland, Montana, and Wyoming. The most extensive area occurs along the coast of California, with small areas reported from Washington, Oregon, and the Great Valley of California. Since most of the chromite deposits in the United States thus far discovered are of low grade and are expensive to extract, domestic production has been small except during war periods when the need for chromium became critical for war industries and imports from foreign countries were greatly reduced. The records indicate that from 1880 to 1946, only 20 per cent of the total production of the United States occurred during the peace years, whereas 80 per cent was produced



(A.) Chromium. Graphic illustration of United States production during the two World War periods. Domestic production during interim years was almost negligible. What percentage of increase was made at peak output for World War II over the corresponding peak of World War I?

during the two war periods, 1914-1918 and 1941-1945. During World War II, the total output of the United States was 356,-858 short tons, of which California produced 47.6 per cent, Montana 42 per cent, and Oregon 8.4 per cent. Small quantities were produced by Alaska, Washington, and Idaho (see Illus. above).

World supplies of chromite. The annual production of chromite for the leading producing countries for which statistics have been made public by the United States Bureau of Mines are given in the accompanying table.

The average annual output of the five leading countries is shown graphically on Illus. below.

In this connection it should be noted that the Soviet Union, probably ranking foremost among the nations in output of chro-

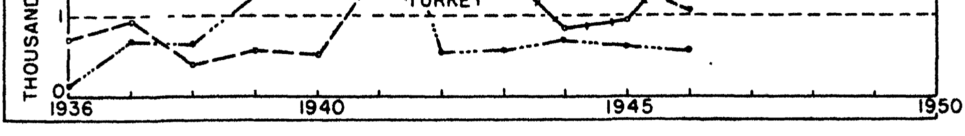
Table X

World Production of Chromite by Principal Producing Countries

(in thousands of metric tons)

	1940	*1942*	*1946*
World	1,158	2,030	1,100
So. Rhodesia	248	318	151
Union of South Africa	161	338	189
Turkey	170	115	109
Philippines	201	50	58
New Caledonia	56	68	25
Yugoslavia	71	100	—
Cuba	52	286	174

Source: *Minerals Yearbook, 1946*, p. 245.



(B.) Chromium. Annual production by principal producing countries since 1936. What trend seems apparent for Cuba? Union of South Africa?

mite and also in reserves, is conspicuously absent. It is known that large reserves have been proved in the central Ural Mountains area, as well as some distance northwest in the Perm area, now known as the Saranovskoe district. Some sources have estimated the total known reserves as high as 7 million metric tons.

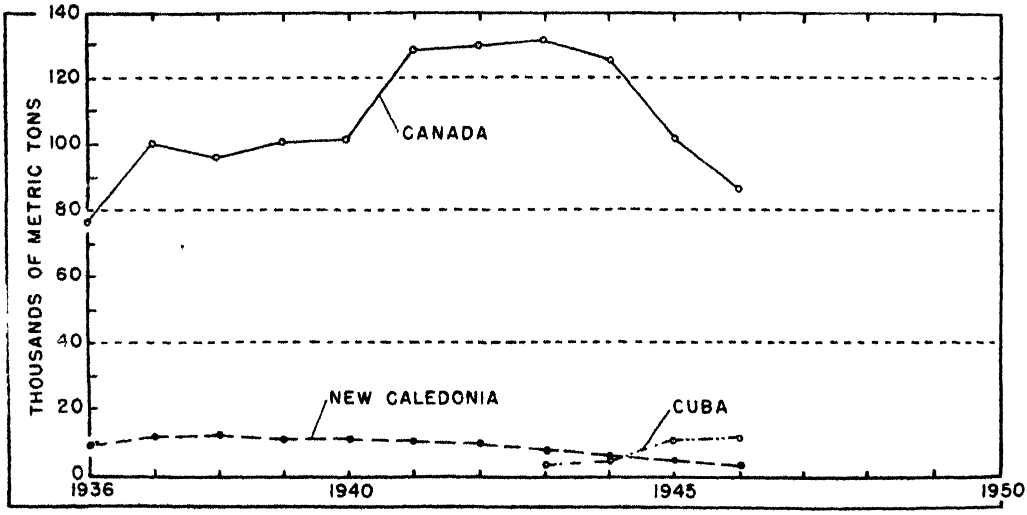
In general, the great industrial nations are the ones that use and must have access to chromium in connection with steelmaking. The demand for chromite is therefore in proportion to the steel output. Aside from the Soviet Union, the great steel-producing countries are dependent upon imports for their supply of chromite. Since chromite is a *must* for steel manufacture, it follows logically that the capital interests of steel-producing nations have invested heavily in chromite-producing corporations abroad. Examples of this may be noted, as British capital in Southern Rhodesia, Union of South Africa, and India, French capital in New Caledonia and Turkey, German capital in Turkey and Yugoslavia, and American capital in the Philippines, New Caledonia, and Cuba.

Nickel

Approximately 60 per cent of all nickel is used in the making of nickel steel, the remainder being used mostly as alloying material with copper, aluminum, and other metals. Nickel alloys are used for steel subject to corrosion, great temperature changes, heavy loads, and abrasion. Low-nickel steels (0.5 to 0.7 per cent Ni) are tough, strong, and ductile. High-nickel steels (7 to 35 per cent Ni) are heat- and corrosion-resistant. Nickel steels are adapted to a wide variety of uses, from cooking utensils and precision instruments to armor plate. Nickel plating is used to prevent corrosion and thus is extensively employed in the manufacture of food containers because of its resistance to attack by weak acids.

Occurrence of nickel. The world's largest nickel-bearing area is in the Sudbury district of Ontario, about 250 miles east of Sault Ste. Marie. The ore area found there is claimed to embrace more than 700 square miles and to have reserves sufficient to meet the world's needs for decades to come. Because of the great output in the Sudbury district, Canadian exports dominate the world's trade in nickel.

Outside of Canada the known deposits of nickel ore are widely scattered, although



Nickel. Annual production of the principal suppliers of the world's nickel since 1936. Production in Canada: 194[illegible], 117,000 tons; 1948, 132,000 tons. Other data will be published later. How does one explain the sharp change of trend by Canada since 1946?

not large. In the nineteenth century, New Caledonia was the leading producer of the world's nickel supply, but since then Canada has held undisputed leadership. Reserves in Caledonia are said still to be ample and easily mined, but the ore is low in metal content.

Ores similar to those at Sudbury occur scattered in small bodies in Norway, but thus far no large reserves have been discovered The largest mine in southern Norway produced 1,500 tons annually before World War II. The largest known nickel deposits in northern Europe are near Petsamo, Russia. Development of this deposit during the prewar period was largely by American capital and 3 per cent nickel ores were being produced. Since production was interrupted by World War II, the future is uncertain as to whether this deposit will again become the foremost center of nickel production in Europe.[1] Nickel has also been found in the Ural Mountains of the Soviet Union, but little is known concerning the reserves. Exploitation to a minor degree has long been reported from Greece.

The United States normally consumes about 50 per cent of the world's supply, the Soviet Union about 15 per cent, Germany about 10 per cent, and the United Kingdom about 8 per cent. The world demand has generally been met by exports from Canada to the extent of 85 per cent of the total and from New Caledonia to the extent of about 10 per cent. Minor quantities have been provided from other sources.

Summary. Nickel is one of the most important metals as an alloy for ferrous and nonferrous metallic products and is considered to be vital as a strategic metal for ordnance purposes. Inasmuch as the Soviet Union has been inadequately explored, it is likely that within its vast territory nickel sufficient for its own needs may be uncovered. During the foreseeable future, Germany and France must depend largely upon output from Norway, Finland, the Soviet Union, and Greece, while the needs of the United Kingdom and of the United States can be met by output from the large reserves of Canada, and those of Cuba.

TABLE XI

WORLD PRODUCTION OF NICKEL BY PRINCIPAL PRODUCING COUNTRIES

(in metric tons, metal content)

Canada .	111,577
U. S. S. R	13,400
Cuba . .	11,000
New Caledonia	8,808
Others .	5,875
World	150,660

Source. Data from copy for *International Atlas* under direction of William Van Royen.

Molybdenum

In the years immediately preceding World War II molybdenum was used as an alloying metal in about 30 per cent of the total tonnage of alloyed engineering steels. During the war period the value of molybdenum became increasingly appreciated, with the result that in 1949 molybdenum was reported to be a component of about 80 per cent of the alloyed engineering steels being made. This increase was due partly to greater availability but mostly to the wider application caused by new uses.

Molybdenite (MoS_2) is the principal ore. Production data are usually given in terms of concentrates which range from 48 to 49 per cent metallic molybdenum and are expressed in tons of ore. However, it is preferable to use data given in terms of metallic molybdenum contained in the ore or concentrate, in which case quantities are stated in pounds rather than in tons. In general, both domestic and foreign data can be, and in most cases have been, converted to terms of metallic molybdenum contained in the ore or concentrate.

It is claimed that molybdenum is the most effective element in contributing high-temperature strength to ferrous alloys. This is of great importance in the construction of jet-propulsion engines, which are

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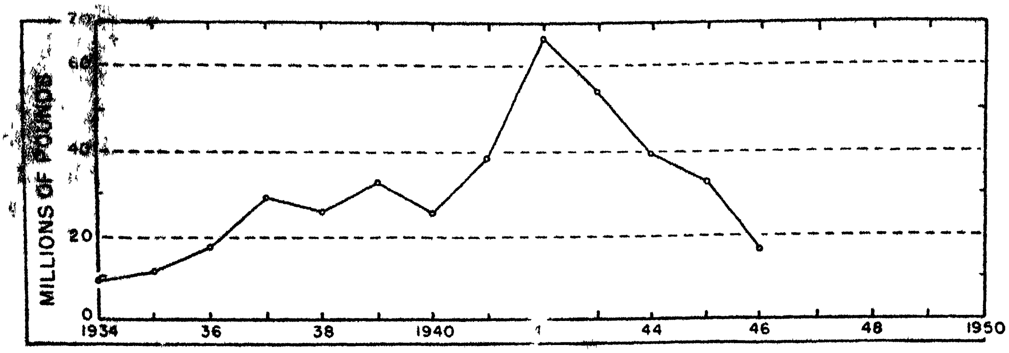
[1] Ceded by Finland to U. S. S. R. in 1944. U S S. R. now probably ranks second in world production

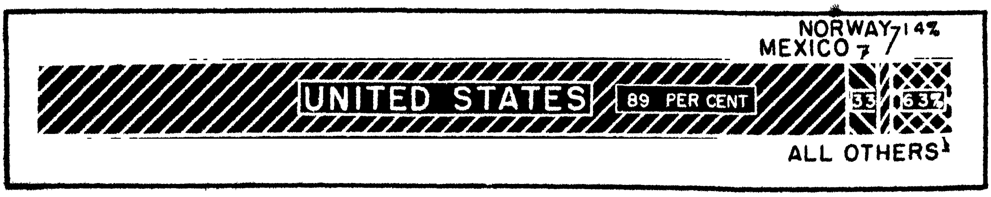


(A.) Molybdenum Annual production in the United States since 1934. Note effect of the war years upon production. Production in 1947 was 27 million pounds, in 1948 it was 26.7 million pounds. How does one account for recent trend shown?

becoming increasingly used in air traffic. In general, however, molybdenum is used in a wide variety of alloy steels and iron, particularly in ordnance and high-tensile steels. It imparts high resistance against "creep" of metal under pressure and it contributes depth-hardness, thereby making possible tools which are adapted to high working temperatures and yet will retain their hardness without becoming brittle upon cooling. Molybdenum is now added to stainless steel to improve resistance to some types of severe corrosion. Furthermore it has been found that molybdenum in connection with chrome and nickel, one or both, makes a superior alloy for use in connection with some parts of gas turbines and automotive parts, as well as in the manufacture of armor plate. About 95 per cent of the molybdenum produced is used in steels and about 3 per cent in cast iron.

Molybdenum is being produced by six states in the Union. Colorado has long been the foremost producer and in 1946 was credited with 60 per cent of the total output of the United States. In 1947, however, Utah took the lead, followed by Colorado, New Mexico, California, Arizona, and Nevada, in the order named. The significance of molybdenum as a strategic material is well shown by graph above, which reveals the prewar output as less than 11 million pounds, the peak output being reached in 1942 at nearly 62 million pounds, from which the decline to 18 million pounds in 1946 was sharp indeed. It may be expected, however, that the molybdenum output during the years ahead will remain substantially higher than was true before World War II.

Molybdenum, in nearly the same degree as chromium, has become recognized as an alloy metal essential for the iron and steel industries. In this metal the United States holds such a predominant position that it is in virtually monopolistic control (see Illus. below). The only other countries with any known stores of molybdenum are Mexico, Norway, and French Morocco. Unless further exploration should reveal sources unknown at this time, the leadership of the United States in output of molybdenum ore

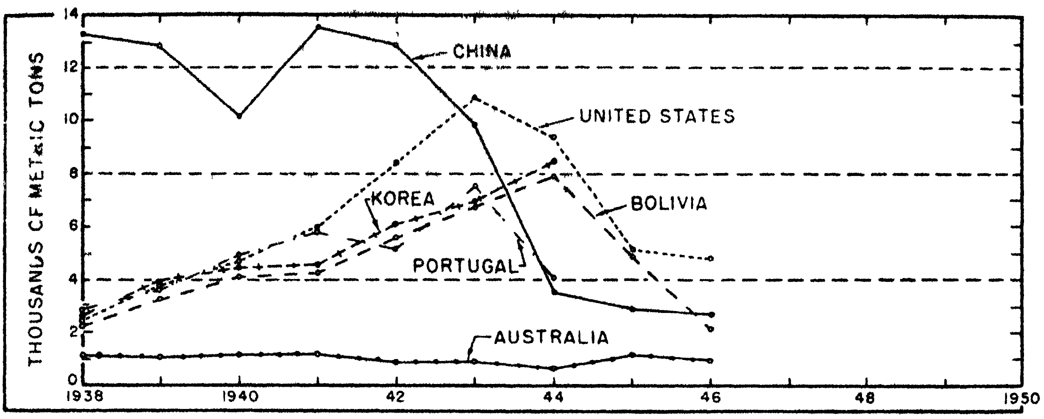


(B.) Molybdenum. Graphic illustration of dominance of the United States in the world production of molybdenum. Percentages are determined on basis of total output during the period 1934-1946.

appears certain to be continued during the foreseeable future.

Tungsten

Tungsten has become almost indispensable in modern metallurgy, and particularly so in alloy steel. Its importance is due to the toughness, strength, hardness, and resistance to abrasion which it engenders in iron alloys. Tools made of tungsten steel are much more durable and can be used more efficiently where hardness and toughness are involved than those having no tungsten content. Tungsten carbide facings on cutting tools of ordinary stock are widely used. If the whole tool is made of tungsten carbide, a substance second only to diamond in hardness, it will last from twenty-five to fifty times as long between sharpenings as will the best ordinary high-speed steel.



Tungsten. Annual production by principal countries since 1938, in terms of tungsten concentrates, 60 per cent WO_3. When was the peak of production reached in China? In the U. S. A ?

High tungsten steels, which contain 15 to 20 per cent tungsten and 4 to 5 per cent chromium or molybdenum, retain timber and cutting edge even at red heat. This quality makes possible the operation of metal-cutting machinery at otherwise impossible speeds and imparts the name "high-speed steel." Tungsten is highly desirable for valves and valve sets in internal combustion engines, where high temperatures are continually met. It is also used in cold chisels, hack saws, files, razor blades, springs, armor plate, and armor-piercing shells.

The most generally known use of tungsten, and one of its most important uses, is as a filament in electric light bulbs. It has high electric resistance and a very high melting point, thus allowing a surprising degree of efficiency in the conversion of electricity into light. No satisfactory substitute for tungsten as an electric light filament has yet been found.

Sources of tungsten ore. The sources of tungsten, by principal producing countries of the world, are shown graphically in the diagram above. Note that in the early 1930's China was the undisputed leader in the world's supply of tungsten, a position that nation held until 1943 when leadership was taken by the United States, a position since retained. Second place was formerly held by Burma, but now there seems to be a close race between China and Bolivia, due largely, no doubt, to the unsettled military and political conditions that have recently afflicted China.[1]

Outside the United States, Bolivia has long been a consistent producer and still remains so, most of the production being from the deposits in the province of La Paz.

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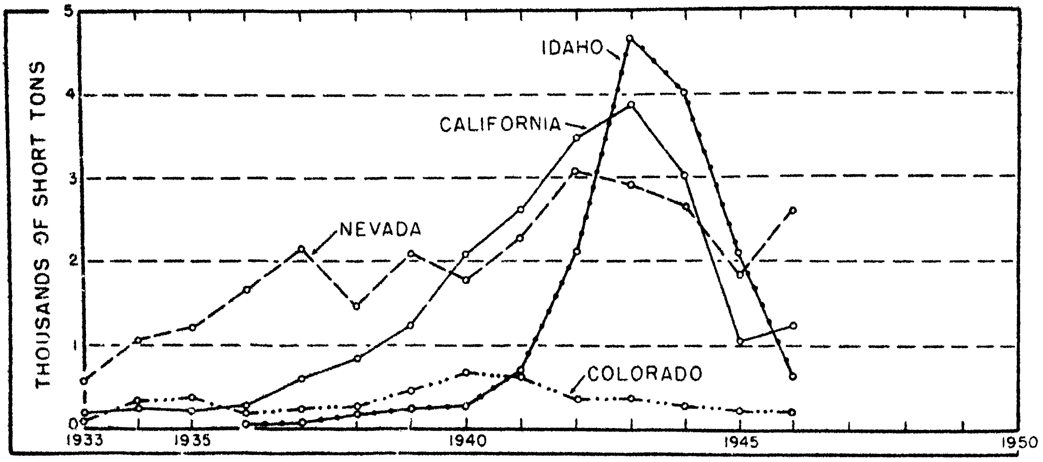
[1] Wolframite is known as the source of tungsten, and all American statistics are given in terms of concentrates, 60 per cent WO_3.

Argentina began production on a modest scale in the early 1930's and under the impulse of high prices reached peak production in 1943, since which time a sharp decline has occurred. It may be expected, however, that production will continue on a moderate basis during the years ahead. Brazil is the big newcomer in the field of tungsten production. Beginning production about 1940, it increased spectacularly to meet the demands of the war period. Since then it has declined, but it still retains an important position as a source of tungsten to meet export demands, particularly in the United States. Latin America promises to continue to be an important source of tungsten in the Western Hemisphere.



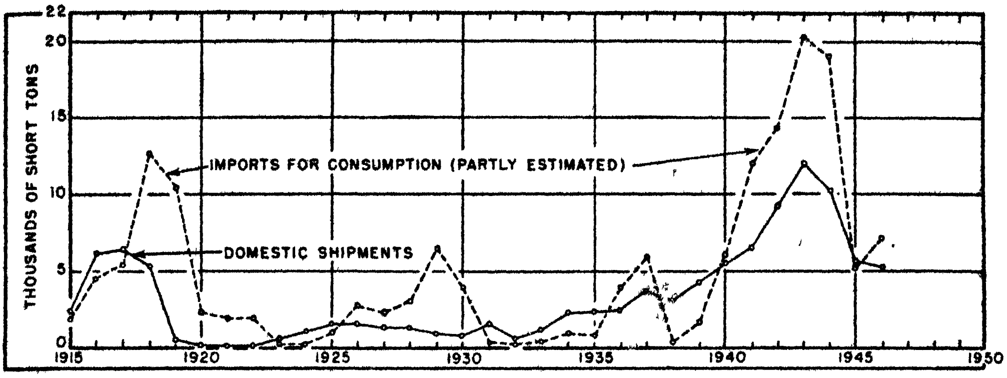
Tungsten. Annual production of leading states in the United States. Which states appear likely to be the principal tungsten producers in the postwar period?

In Europe, Portugal has long held an important position in its output of tungsten ore. The country was strategically situated to supply ore to the central powers of Europe and the Western Allies during the war period, and as a result prices soared and the output of tungsten in Portugal was increased twentyfold by the time the peak was reached in 1943. Since then there has been virtual collapse, but production may be expected to be resumed on a modest basis in the near future. No other country in Europe has provided any appreciable amount of tungsten ore.

In Asia, China, long in the lead, and Burma have been the principal sources, although smaller amounts have been produced by the Malay States. There seems no doubt that the reserves in China are large, and they may be so in Burma; therefore, when industrial and trade conditions return to more nearly a normal status, output of tungsten ore is expected to be resumed on an important basis in these two centers of long standing.

Australia likewise has produced tungsten ore in moderate quantities for many years, but unlike some of the other centers of production, its decline from the war peak in 1943 has been comparatively moderate.

The total output of tungsten ore in the United States reached its peak in 1943, but this was followed by a decline of more than 50 per cent in 1946. Colorado, long famous for its sustained production, has been relegated to fourth position among the states, and first place in output seems to be a close race between Idaho and Nevada. As indicated by the accompanying graph, see above, Idaho took leadership from California in 1943 and held it until 1946, when Nevada assumed first place. In general it



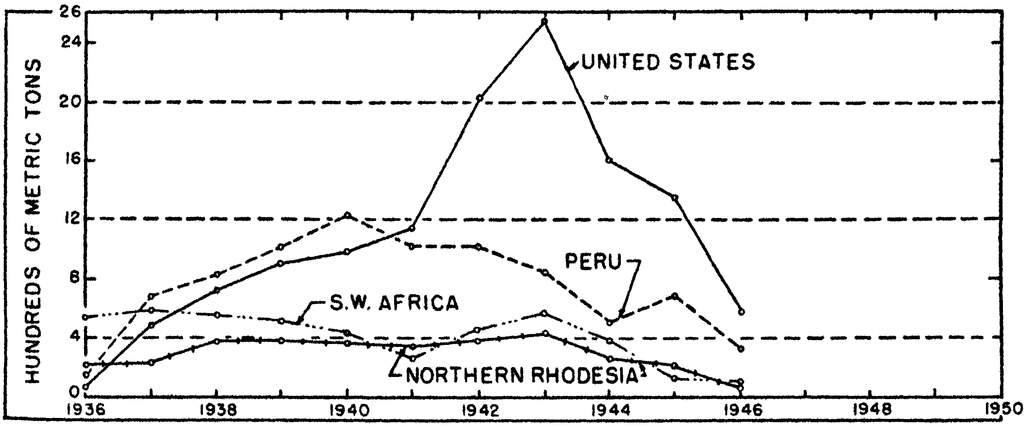
(A.) Tungsten. Imports for consumption and domestic production represented by shipments in the United States annually since 1915. When did the sharp upswing in both imports and production occur? Suggest reasons.

may be said that the trend from war to postwar conditions revealed a sharp decline but that the trend for the immediate future may be expected to be in line with that of the production of iron and steel, and therefore that the production curve will conform in a general way with the changing trends of industry in the United States (see Illus. B, p. 348 and p. 424).

Summary. The significance of tungsten as an essential material for war industries and for ordnance is emphatically illustrated in the total world output, which dropped from 61,000 metric tons in 1943 to 19,000 metric tons in 1946. For the foreseeable future, the centers of output of this alloy material, vital in so many phases of the iron and steel industries, will continue to be the United States, Bolivia, Brazil, China, and Australia. In this connection, however, we must bear in mind that we have no late data concerning the prospects in the Soviet Union, where it would appear that possibilities for discovery of tungsten deposits are great, and that the collapsed political conditions in China and Burma render the situations there uncertain for the time being.

Vanadium

The principal use of vanadium is in making alloy steels and iron. It is used in steel



(B.) Vanadium. Graphic illustration of annual production by the principal producing countries since 1936. What countries have supplied the greater part of the world's vanadium since 1938?

both as an alloy and as a scavenger. It removes oxides and other impurities, and at the same time it increases the strength and induces finer texture of the steel through grain refinement. Chrome-vanadium steels are used extensively in railway and bus operations and are of great importance in ordnance manufacture. Vanadium is classified as a "critical" metal by the Army and Navy Munitions Board, which implies that it is nearly as essential as the metals classified as "strategic." Vanadium differs from some of the other alloy metals considered in that it is not applicable to stainless steels, wherein high temperature and high strength qualities are of prime importance. In 1946, 52.4 per cent of the vanadium was used in the manufacture of high-speed steel, 10.8 per cent in other types of tool steel, 25.8 per cent in other alloy steels, and 4.8 per cent in nonferrous alloys. The remainder, 6.2 per cent, was used largely for chemical purposes and to some extent for other lines of metallurgical products.

Prior to World War I, Peru was the world's principal producer of vanadium and had been so for several years; during the decade following, increased production in Southwest Africa brought that area into the premier place until 1938, when Peru again forged to the front for a period of three years. The United States, with nearly all the output being provided by Colorado, Arizona, New Mexico, and Utah, now holds a commanding position in the output of vanadium, having assumed that position in 1941. As was also true for most of the other alloys, the demands of war created a temporary but urgent call for vanadium which induced rapidly expanding production in this country. Measured in terms of vanadium content in the ores and concentrates, only a little more than one million pounds were produced in 1937, contrasted with 5,586,000 pounds in 1943. The postwar decline was nearly as precipitous as the rise, as is shown by the drop to 1,272,000 pounds in 1946. Details of these trends are shown graphically for the United States and the other important producing countries on page 453.

Inasmuch as the demands of the times call for increasing speed of machines, automobiles, and planes, it seems certain that the ferroalloy metals essential in the manufacture of high-speed steel will all face gradually increasing demand, and, to meet it. increasing output. The curve of production of vanadium will probably correspond roughly to the curve of production of high-quality steel. Among the nations of the world, in the light of present knowledge, the position of the United States as the leading contributor of vanadium appears to be safe. In this, however, as in the case of some of the other alloys discussed, we must bear in mind that statistics or other evidences of production in the Soviet Union are not available. The iron curtain so far has deprived the rest of the world of any authentic information while, on the other hand, the Soviet Union has not been deprived of such information by the other countries.

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Chapter Twenty-six

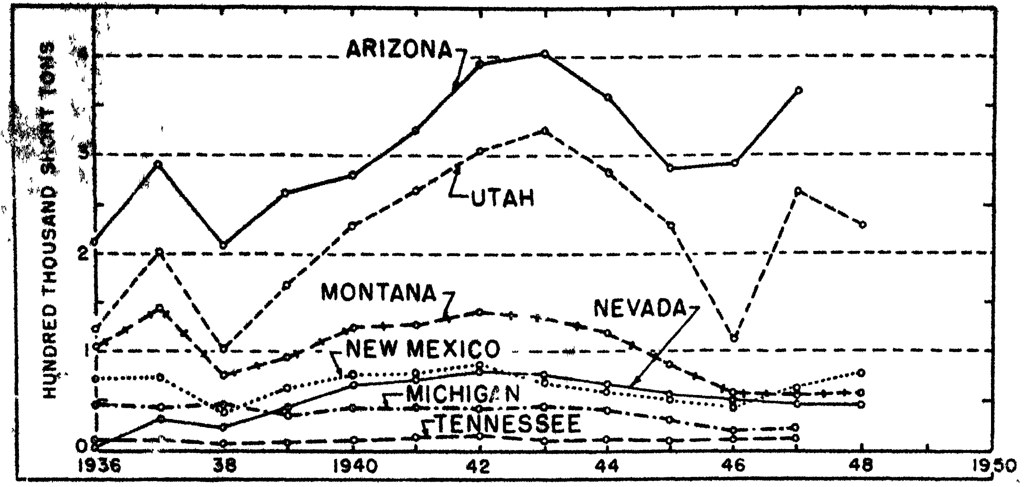
PRINCIPAL NONFERROUS METALS—THEIR GEOGRAPHICAL DISTRIBUTION AND INDUSTRIAL IMPORTANCE

ALTHOUGH THE INDUSTRIAL WORLD uses more iron and steel than any other metal, the nonferrous metals are equally important in providing the goods and services deemed necessary for modern standards of living. The nonferrous metals which are usually considered to be of major importance in themselves, rather than as alloys, are copper, aluminum, lead, zinc, and tin. Magnesium is of some importance as a metal alone, but its value to industry is based chiefly upon its use as alloying material with aluminum. Of these nonferrous metals, the potential reserves or sources of supply of aluminum and magnesium are such that scarcity during the foreseeable future need not be feared. Such is not the case, however, with the other four. The demands for copper, lead, zinc, and tin are so heavy and persistent and the known reserves of ore so limited that scarcity in the not distant future is threatened. In fact, it is already manifest in some areas. It is imperative, therefore, that conservation measures be practiced through emphasis on the saving of scrap metal and on its reuse as a secondary source in the manufacture of wares of various kinds.

Copper

The use of copper earlier than of some other metals was probably due to the fact that it was found as native copper in a few places and so could be used directly without further conversion. Furthermore, copper could easily be hammered and fashioned into desired forms. Its uses were limited by its softness, but the discovery was made early that by fusing it with tin, also occasionally found as a metal, an alloy much harder than either could be obtained. This substance, *bronze*, was far superior to stone for making tools and weapons, and thus man progressed from the New Stone Age (Neolithic) into the Bronze Age. Copper was used alone where hammering into desired shapes was essential, as for pots and pans and ornaments, and in alloys with other metals where hardness was desired. Bronze was used for coins because of its durability and the readiness with which symbols could be stamped upon it.

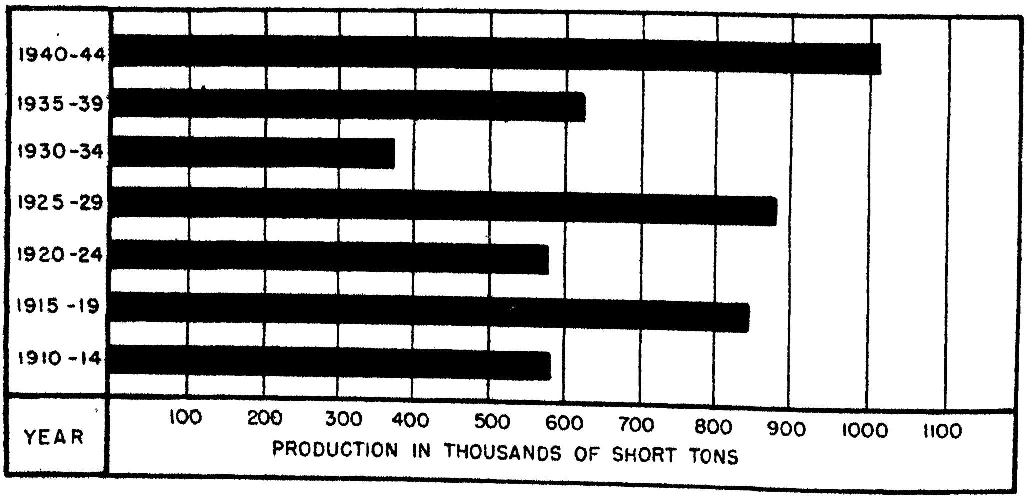
Although from very early times copper ranked among the most desired metals, the demand grew but slowly until the development of the electrical industries gave rise



(A.) Copper. Annual production of the seven leading producing states since 1936. Note the upsurge of production during the war period and interpret the postwar curves.

to an unprecedented need for copper in connection with generating and transmission facilities. Copper met this need because of its several essential properties, but especially because of its conductivity of electrical energy, its ductility, and its malleability. Ductility makes possible the fine copper wire now essential in electrical equipment, while malleability permits hammering the metal into plates and sheets.

Copper ores. Ores varying from native copper occurring in local masses to complex chemical combinations are found in formations of nearly all geologic ages. Generally the ores of copper are more complex than those of iron; and since they occur disseminated in rock masses, the ore as mined consists of a small percentage of copper compounds and a high percentage of rock material known as *gangue*. Some



(B.) Copper. Graphic representation of the production in the United States from domestic ores by five-year periods since 1910. How does one account for the three high production periods indicated? Suggest reasons for the low production of one of the five-year periods.

of the largest and most important mines are yielding ores which contain only 1 to 3 per cent recoverable copper, while ores which yield 9 per cent or more are deemed to be exceptionally rich.

The distribution of copper mining in the United States and Canada. Roughly, 90 per cent of all the copper mined in the United States comes from Arizona, Utah, Montana, New Mexico, and Nevada (see Illus. A, p. 456). Other states with significant production are Michigan, Tennessee, Washington, and California. In a number of places copper is a valuable by-product of ores mined chiefly for their content of other materials.

The heavy drain upon domestic resources of the copper ores caused by war conditions is clearly shown in Illus. B, p. 456 (graphs from 1910 to 1944). During the war years, 1940-1944, the average annual smelter production of the United States from domestic ores was 1,002,132 tons. The all-time peak production was reached in 1943 with 1,090,061 tons. In the postwar period the demand for copper is of course less, but with the rapidly expanding electrical industries the general trend may be expected to show an upward curve from the 608,000 tons reported for 1946. Mine production in 1948 was reported at approximately 826,000 tons of recoverable copper; this rate of advance since 1946 seems too rapid to be expected to continue.

Arizona has consistently maintained commanding leadership among the states with a yearly output of 250,000 to 350,000 tons of recoverable copper. The greatest producing districts of the state are in the southeast portion from the Mexico border northward to beyond Tucson (see map, p. 459). In this area the Globe-Miami, Bisbee, and Jerome districts have become familiar names in the copper world because of the magnitude and availability of their reserves. The ore bodies vary from low-grade available by open-cut mining to those of higher grade but of much more restricted extent. While the districts named are the largest and generally the best known, there are also a number of smaller districts being actively exploited, the total output giving Arizona unquestioned supremacy among the copper-producing states. This rank seems assured for many years to come because of the large reserves known to exist in that state.

The main copper-mining center of Utah, the Bingham Canyon district south of Salt Lake City, is the major single producing district of the United States. The copper content of the ores is only 1 per cent or less, but such large-scale operations can be carried on that even this low-grade ore has proved highly profitable. The annual copper output during the war period averaged 281,000 tons but dropped to 114,000 tons in 1946. A gradually rising trend from the latter figure may be expected during periods of high industrial activity. It is reported that the amount of ore still in reserve gives promise of the continuance of Utah's high production for several decades.

Montana has generally ranked third in annual copper production since 1925. The chief center of mining operations is the famous Butte district in the heart of the northern Rockies. Although large-scale production has been maintained for several decades, recent extension of operations to include hitherto unworked ores of lower grade and the large proved reserves of unmined ore indicate that mining will continue to be important for many years to come. The average copper output of the state in years of normal industrial activity may be expected to exceed 50,000 tons (see Illus. A, p. 456).

In 1936 Nevada displaced Michigan from fourth place among the states in output of copper and held that rank until 1943, when she was overtaken by the rapidly increasing output of New Mexico. Present trends indicate close competition for the fourth and fifth ranking positions among the states in copper output, and either state may in the near future crowd Montana from the third place held for some years. Due to persistent decline in Montana's copper output since 1943, New Mexico stepped into third place in 1947, but the differences in production are so small that the rank of

Montana, Nevada, and New Mexico may change any year. As a group, however, these states will probably follow Arizona and Utah for some years to come.

The northern peninsula of Michigan has long been noted for its output of copper. The Indians made some use of the native copper which they found in small bodies in the glacial drift and in stream gravels. To the French explorers who came to this region they told stories of hills of copper back from the edge of Lake Superior. Later these uplands became one of the greatest copper-producing districts of the world. The ore consists of rock impregnated with metallic copper. For many years Michigan ranked first in copper output, but she lost this position with the large developments in the western states. Michigan now ranks sixth, and because of increasing depths to which mining operations must extend and the gradual depletion of available ore the trend of output will probably continue to decline. (See Illus. A, p. 456.)

CANADA. Canada is characterized by widespread deposits of copper ores from Quebec to British Columbia, and some discoveries have been reported from the Northwest Territories. Production, based on metal content of ores mined, was generally below 60,000 metric tons until after 1926, when the rapid increase in output began. Production more than doubled by 1930 and reached an all-time peak of 256,294 metric tons in 1940. (See Table XII.)

TABLE XII

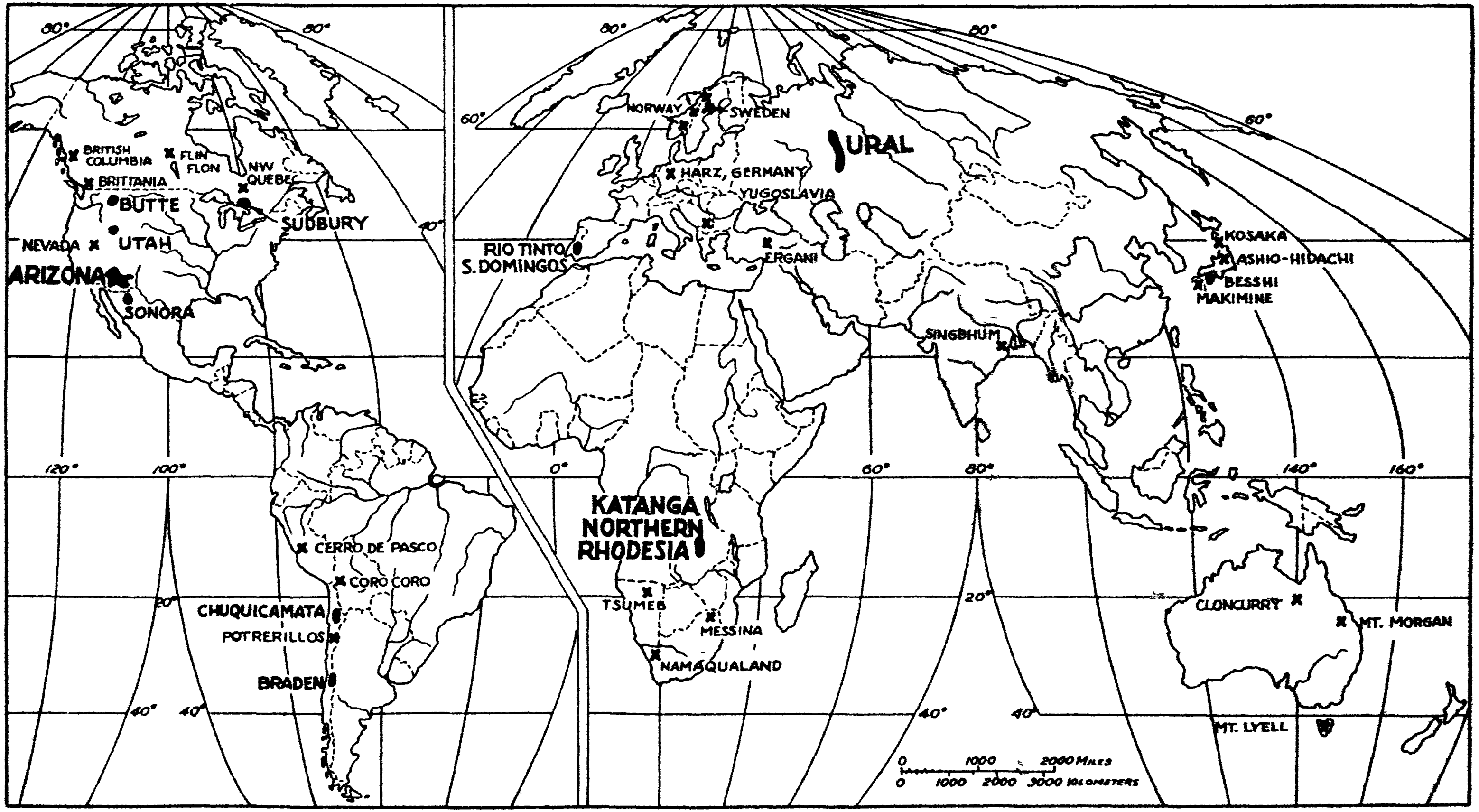
COPPER PRODUCTION IN CANADA
(copper content of ores mined)

1926	60,371	metric tons
1930	137,655	" "
1935	175,893	" "
1940	256,294	" "
1942	244,040	" "
1944	224,049	" "
1945	200,095	" "
1946	151,499	" "
1947	......	
1948	......	
1949	......	
1950	......	

The nickel-copper mines of the Sudbury district of Ontario usually produce about 50 per cent of the Canadian output. (See World Map, page 459.) Northwestern Quebec ranks second in rank of output, and the Flin Flon mines of Manitoba and Saskatchewan constitute the third important center of copper-mining activity in Canada. British Columbia, although of lesser importance to date than the more eastern centers, a vast area wherein possibilities for further discoveries and development exist. On the whole, it is too early to forecast continued decline in Canada's copper output. As world demand increases, as now seems almost certain, the search for new ore bodies will be intensified. In that search Canada will undoubtedly play an important part.

Distribution of copper smelters and refineries. Because of the large amounts of impurities with which copper ores are invariably associated, the percentage of metal is always low. Thus the ores as mined yield only 1 to 8 per cent of copper, whereas the iron ores mined in the United States yield 40 to 65 per cent metallic iron. Since the ore is too bulky in relation to value to bear the expense of long haulage, *copper smelters* must be located near the mines. At the smelters the ore is reduced to "blister," which contains 98 per cent or more of metallic copper. For many purposes, however, especially for use in the electrical industries, the metal must be almost 100 per cent pure. Purification is accomplished in the *refineries,* where by electrolytic methods the impurities are reduced to the point where the copper contains only a few hundredths of 1 per cent of foreign matter. For these operations, expensive equipment and cheap electric power are required, and the plants that have proved to be economically practical must be large enough to handle the copper blister from several smelters.

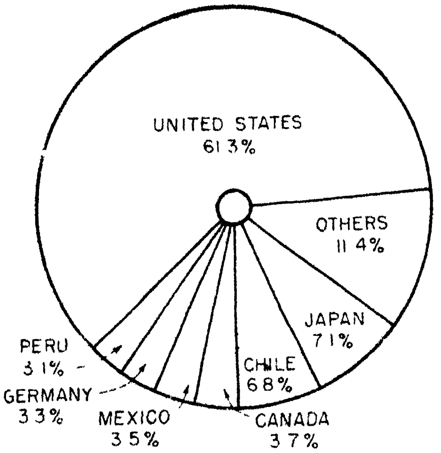
In the United States most of the copper refineries are located near the Atlantic seaboard close to the centers of consumption.



Map of the principal copper ore producing regions of the world. The importance is based largely on quantity output, indicated by the prominence of lettering used.

In addition to their supplies from American smelters, these refineries receive copper in various forms from foreign sources, particularly from Chile, Mexico, Peru, Africa, and Canada. Refineries have also been established at Tacoma, Washington, and in the interior in connection with the large mining properties near Great Falls, Montana, and at Hubbell, Michigan.

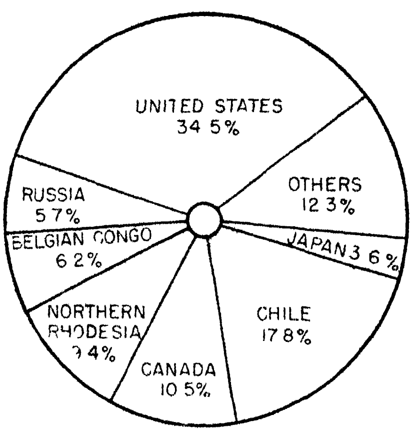
Copper production: Mexico. Mexico has quite consistently produced from 30,000 to 60,000 metric tons of recoverable copper, mostly from the mining district of the northwest part of the country which is a continuation of the general structural conditions in southern Arizona (see Illus. p. 459). The mines are owned and operated, for the most part, by American capital. The prospects are for maintenance of moderate production, perhaps 2 to 3 per cent of the world output during the next decade.



(A.) Copper. Percentages produced annually by each of the leading countries during the 1916-1918 period.

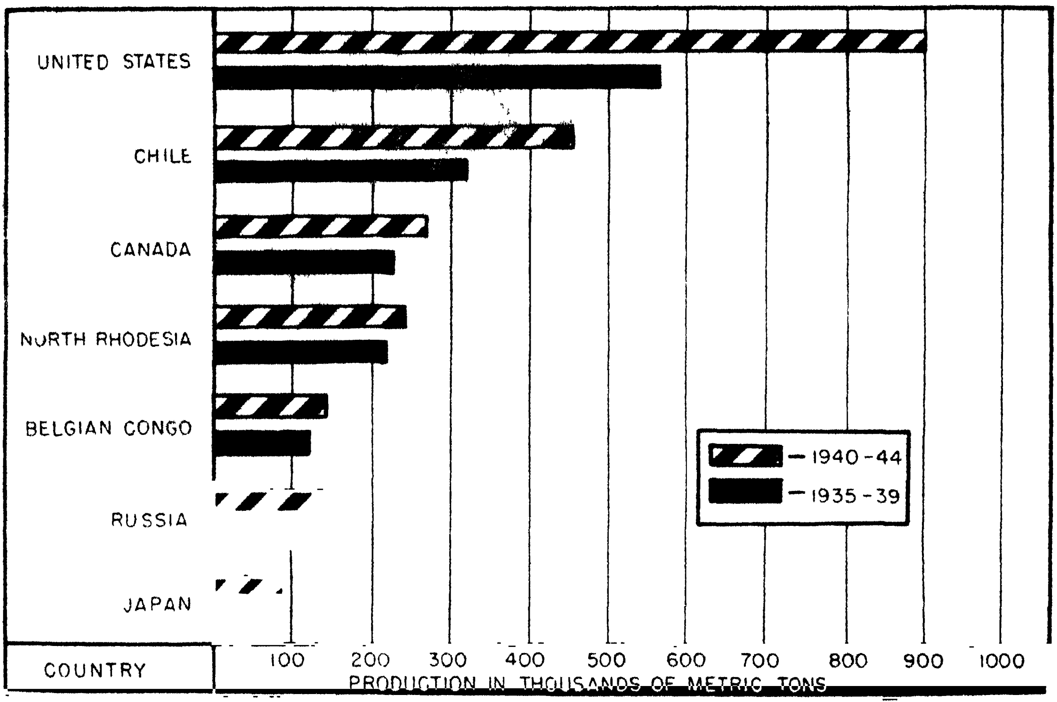
Peru and Chile. In Peru, the Cerro de Pasco mines north of Lima have long been noted for their copper output. During the recent period the production declined from 44,000 metric tons in 1940 to 24,600 metric tons in 1946, a persistent downward trend even during the war years of high demand. Since 1910 the annual production of recoverable copper has generally been below that of Mexico.

Chile's position as one of the important copper-producing countries of the world dates back to the early part of the present century. Since 1920 she has ranked second among the nations (see Illus. below). The average annual output during 1935-1939 was 325,000 metric tons and, during the five-year period following, was 463,000 metric tons. The principal centers of production are Chuquicamata, Potrerillos, and Sewell (Braden) (see Illus. p. 459). The ore bodies occur along the west flanks of the Andes. Ocean haulage is within easy reach, an important factor in obtaining needed supplies from abroad as well as in providing cheap outlets to the world's markets. The ore reserves, proved and probable, have been reported so large that the copper-mining industry of Chile seems assured of long life. For the reasons given, the upward trend of production seems likely to continue, and Chile's position as one of the leading copper-producing countries of the world appears to be well established.



(B.) Copper. Percentages of the world's production contributed by each of the principal producing countries annually during the 1940-1944 period. For Japan, only the one-year period, 1940, was available, and for Russia, only the two-year period, 1940-1941, provided available statistics. Note particularly the changes in percentage credited to the United States and Chile compared with the World War I period. What new centers have become highly prominent since the earlier period?

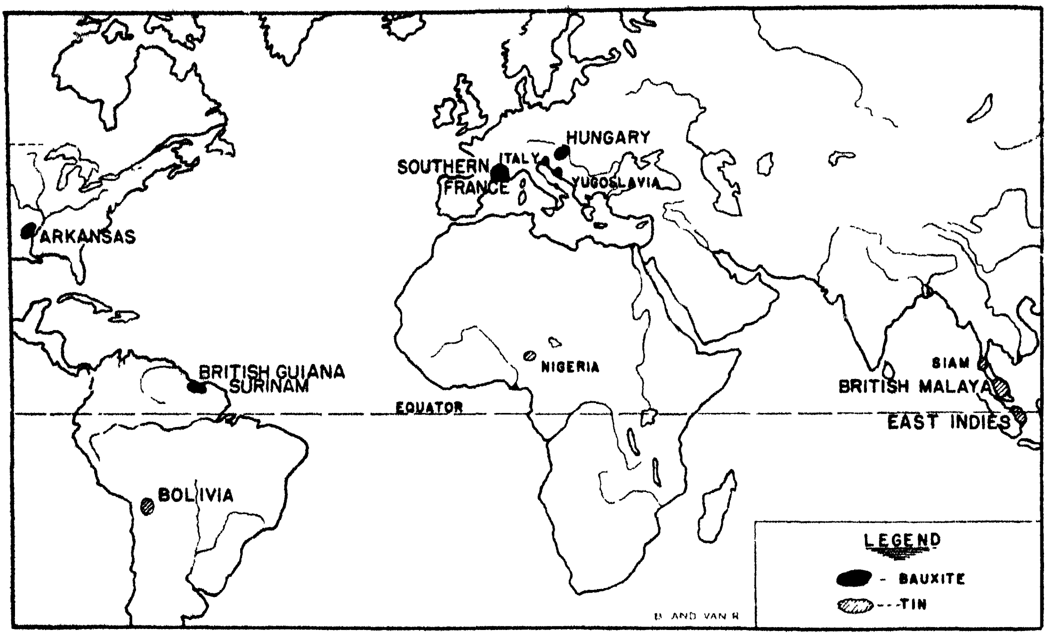
Africa. The principal copper-producing districts of Africa are in the deep interior, where plateau topography is prevalent and rainfall abundant, quite in contrast to the seaboard location and the desert conditions which characterize the Chilean ore fields. The remoteness of the African copper mines from low-cost ocean haulage is compensated in large measure by the greater richness of the ores. The foremost center of production is in northern Rhodesia, where huge deposits of copper ore have been discovered. Exploitation has made this area foremost in the Eastern Hemisphere (see Illus. p. 459). The average annual output in 1940-1945 was about 225,000 tons. The Belgian Congo territory to the north, known as the Katanga district, ranks second in Africa, with an annual output during the war years above 160,000 metric tons. The ores thus far worked in Katanga and Rhodesia have averaged nearly 6 per cent copper, more than five times the average content of the ore now mined in the United States (see Illus. below).



Copper Mine production for each of the principal producing countries for the two 5-year periods indicated. Note particularly the increase in production for the war period indicated for each of the countries.

Formerly the Katanga and Rhodesian output was handicapped by great distances and the high costs of overland transportation. These were in large measure overcome by the opening of the Benguella railroad in 1931, which provided an outlet to the west at much lower cost than was possible toward the south or east. The overland mileage was reduced about 250 miles and the ocean distance about 2,600 miles, thus bringing the African mines nearly 3,000 miles closer to European markets. These improved transportation facilities have placed the African mines in position to compete in the world markets with the great copper-mining districts of North and South America. Furthermore, the Katanga and Rhodesian ore bodies occur under favorable mining conditions; the ores are rich, labor is comparatively cheap, and water supplies are ample for all needs.

The capital interests involved in Africa are predominantly British and American. The ore reserves of Katanga and Rhodesia are so great that these districts, with production that nearly equals and in some years exceeds that of Chile, are now among the foremost areas of exploitation in producing the world's supply of copper. Furthermore, although American supremacy in the copper industry may not be overthrown, the percentage of the world's output contributed by the United States will undoubtedly be further reduced (see Illus. p. 461).



Map showing the principal bauxite and tin ore producing areas of the world. Observe the distinction in symbols used for these two metallic ores.

Other important copper-producing centers. The widespread occurrence of copper ore is revealed by the fact that its mining is an industry of commercial significance in every continent except Antarctica. In the Western Hemisphere, Canada, Mexico, Peru, and Cuba have important copper-mining activities, although they are greatly overshadowed by the United States and Chile. In Europe, the mining of copper ore has been important for centuries in Spain, Yugoslavia, Germany, and Scandinavia; and although late statistics are not available, it is known that the Soviet Union has a rapidly expanding industry with large potentialities for the future. In Asia, Japan is fairly well supplied with reserves of copper ore and she can expand her output to meet the needs of her growing industries. Although weak in coal, petroleum, and iron ore, Japan possesses her own dependable stores of copper ores.

Aluminum

Aluminum is one of the most abundant elements in the earth's crust, but ordinarily it does not exist in a form that makes extraction easy. It occurs in clay, kaolin, feldspars, and other minerals which, although very abundant, are not yet commercial sources. Despite the fact that scientists had been working for a number of years to devise means of extraction which would be commercially successful, as late as 1890 aluminum was referred to as a curiosity; the cost of extracting it from the ores was so great that it had practically no commercial importance. The price was then more than two dollars a pound, while in recent years it has sold below fifteen cents per pound.

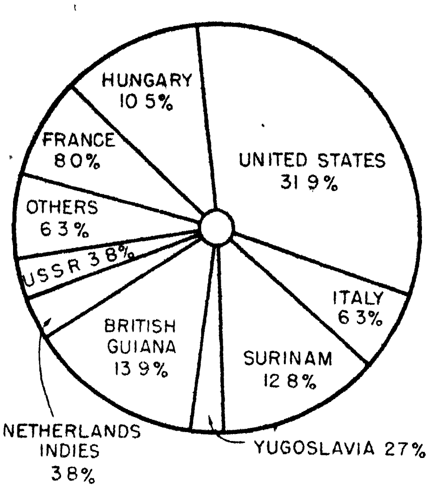
Bauxite is the principal ore of aluminum, and present indications are that it will remain so for a long time. It is a chemical compound of aluminum, oxygen, and water, and it is associated with certain other elements occurring as impurities in the ore. If pure, bauxite would contain 39.13 per cent aluminum, but as mined it contains only 30 to 35 per cent of the metal.

Bauxite is known to have wide occurrence in the world. France and the United States have long been the leading producers, but as a result of German war preparations, the annual bauxite production of Hungary exceeded that of the United States during the last half dozen years for which reliable data are available. During the war years, British Guiana and Surinam attained world leadership by a wide margin. Other important producers were and still are Yugoslavia, Italy, the East Indies, and the Soviet Union. Valuable deposits are reputed to have been discovered in Spain and India, but commercial production is as yet on a small scale.

In the United States, bauxite is known to occur in a number of places, the most important being in Saline County, Arkansas, where more than 90 per cent of the total output of the country is mined. It is also found in Alabama, northern Georgia near Keensburg, and on the slopes of Missionary Ridge in Tennessee. The reserves of bauxite in the United States are estimated to be 26,600,000 tons of ore with content of alumina of 45 per cent or more and 2½ million additional tons with alumina content of 30 to 45 per cent.[1] Alumina is expressed chemically as Al_2O_3.

Uses of aluminum. The properties of aluminum that give it high industrial value are lightness, strength, electrical conductivity, and resistance to corrosion. Metallic aluminum, weight for weight, is twice as good a conductor of electricity as is copper.

The pure metal is comparatively soft and ductile, but where fused with other metals, the resulting alloy may have qualities comparable with those of structural steel. A slight addition of copper to aluminum makes an alloy much stronger than either metal alone. Other elements commonly used in the commercial alloys of aluminum are magnesium, manganese, zinc, and iron.



Bauxite. Average annual production in terms of percentages by the principal countries of the world, 1940-1944. Note the high percentage rank of the United States and observe from the map (previous Illustration) the one place in this country that contributed this large proportion of aluminum ore. In 1948, Arkansas produced 1,429,000 tons of bauxite, which was about 90 per cent of the total production of the United States that year.

New uses for aluminum are continually being discovered, uses which carry it into the realms of manufacture of furniture, machinery, and electrical equipment. Among the most interesting developments in the use of aluminum are those associated with transportation, embracing all the principal branches on land, on sea, and in the air. Aluminum and its strong alloys have entered into the construction of railroad equipment, freight containers, commercial truck bodies, ships, and airplanes. In recent years they have even entered the realm of heavy construction in the form of structural metals for bridges and large buildings. From the standpoint of quantity of aluminum used, the foundry and metal-working industries rank second to the manufacture of transportation equipment. Approximately half the weight of an airplane is due to aluminum. The electrical machinery industry is third in importance. It has been expanding rapidly in late years because of the use of aluminum for electrical conductors for high-tension transmission lines, where aluminum steel-reinforced cables are standard construction. Substantially reduced costs of manufacture have placed aluminum ware within the reach of nearly all households and have opened up huge markets for such products.

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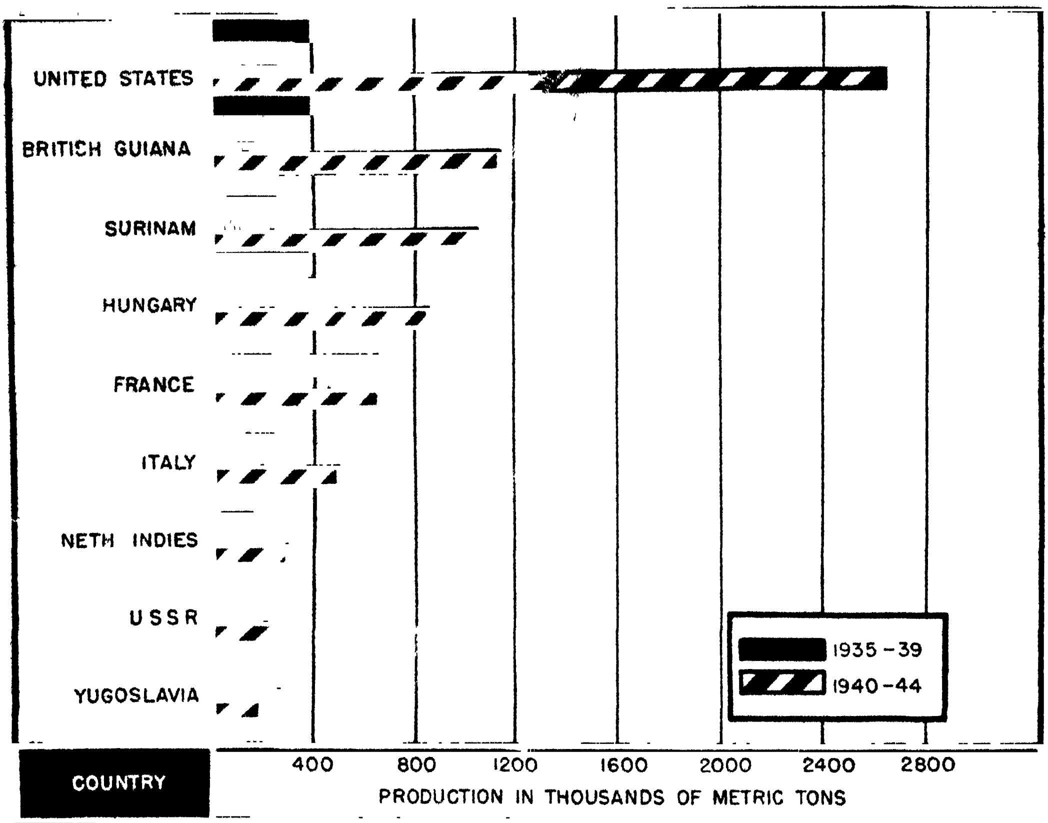
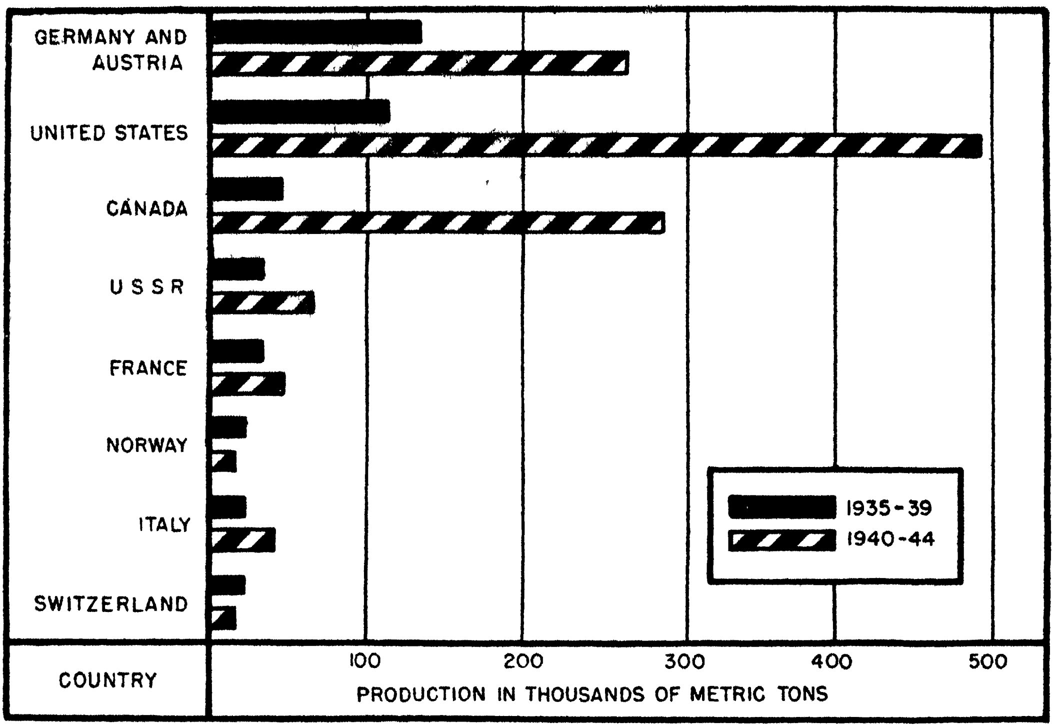
[1] Burchard, E. F., "Bauxite Resources of the United States," U. S. Bureau of Mines, *Report of Investigation No. 3598*, 1941.



Bauxite. Average annual production during the pre-war years, 1935-1939, and the World War II years, 1940-1944. Which country had the highest percentage and quantitative increase of bauxite production? What other western hemisphere sources ranked nearly as high? Which European sources actually produced less bauxite during the war period than during the pre-war years?

From 40 to 70 per cent of the bauxite output of the United States is used for the extraction of aluminum. In addition, however, bauxite enters directly into the manufacture of abrasives and chemicals. In some years the abrasive and chemical industries have used more than 60 per cent of the total output of this ore, but ordinarily bauxite is primarily valuable as the raw material for the manufacture of aluminum.

Conversion of bauxite into aluminum. Where mined, bauxite is bulky and of low value in proportion to weight; hence it is necessary to remove by chemical treatment most of the moisture and impurities before long and expensive freight haulage is undertaken. Where the bauxite is so located that it can be reached only by rail, such processes occur relatively near the mines. Where water haulage is possible, as is the case in Surinam and British Guiana, the ore can be shipped long distances to overseas markets for smelting. In the United States, East St. Louis, Illinois, is one of the oldest centers for reducing bauxite into alumina. Reduction plants for converting bauxite to alumina have more recently been established at Hurricane Creek, Arkansas; Mobile and Lister Hill, Alabama; and Baton Rouge, Louisiana. Mobile and Baton Rouge, like East St. Louis, may receive bauxite from British Guiana and Surinam by water routes and thus avoid long rail haulage for the bulky raw material. It should be borne in mind, therefore, that bauxite mined where water haulage is not practicable will generally be treated and converted into alumina at points not distant from the mining operations, whereas in cases where water haulage from the mines is practicable, long ocean voyages may bring the ore to reduction points located at seaports, where it is converted into the concentrated alumina.



Aluminum. Average annual production of principal countries during the pre-war and World War II years. Which country ranked first in aluminum production during the pre-war years?

After chemical treatment and removal of impurities the product, alumina, is much lighter and more valuable than the bauxite from which it was derived. The output of alumina from the ore-reduction plants provides the raw material used by the refining plants in the United States. In these plants alumina is reduced to refined metallic aluminum. Conversion into metallic aluminum involves removal of the chemically combined oxygen, a process comparable to the smelting of iron ore to pig iron. This conversion is accomplished by electrolytic processes, and since heavy use of current is necessary, most of the refineries are located where cheap hydroelectricity is available. The most important reduction plants in North America are located at Alcoa, Tennessee; Massena and Niagara, New York; Badin, North Carolina; Vancouver and Spokane, Washington; Los Angeles, California; and Arvida, Quebec, Canada.

The third step of manufacture is the shaping of the metal into the forms demanded by the trade. The widely scattered factories engaged in this part of the production process obtain their bars of aluminum, known as *pig aluminum,* from the electrolytic reduction plants.

Foreign sources of bauxite and aluminum. Prior to 1940 France consistently held first place in the production of bauxite, accounting for about 20 per cent of the world's output. During the war years the United States, British Guiana, Surinam, and Hungary all expanded their output to an unprecedented degree, while French production showed little change (see Illus. p. 464).

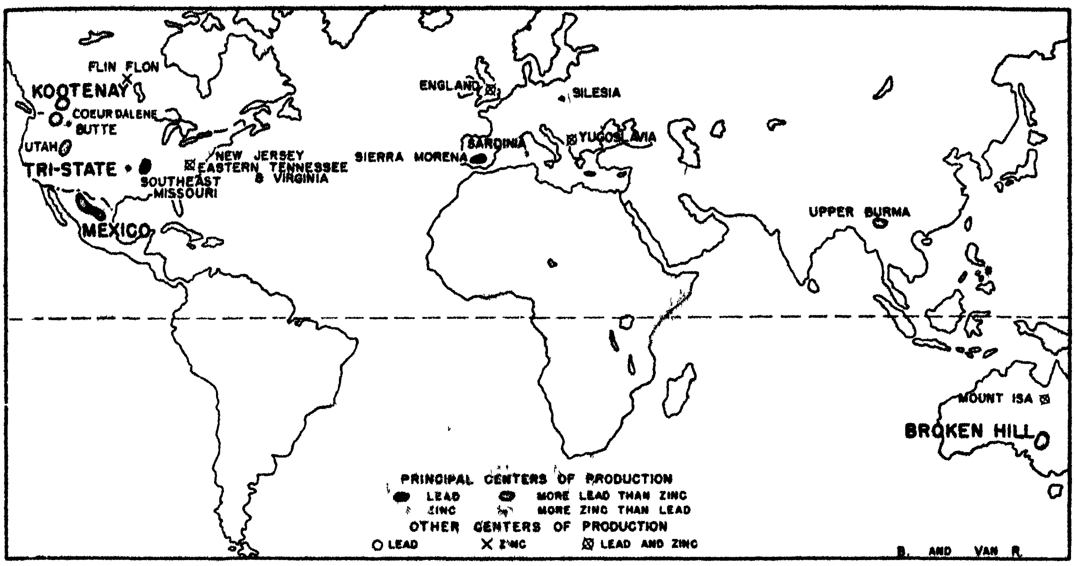
It is significant, however, that a number of the leading bauxite-producing countries are not important producers of metallic aluminum. The reason is that the ore is generally transported to the great reduction centers, which are not always located within the ore-producing countries. Before 1940 Germany and the United States were by far the major producers of aluminum, each with an average annual production above 100,000 metric tons (see Illus. p. 465). As a result of large-scale preparation for war during the period 1937-1939, Germany moved to first place with annual production of over 150,000 metric tons, although its sources of bauxite were mainly outside of Germany proper. The United States followed with an average of nearly 140,000 metric tons per year. Since 1939 the production of the United States has expanded rapidly, as has that of Canada, which now ranks second among producers. In order of probable importance, these countries are followed by the Soviet Union, France, Norway, Italy, and Switzerland.

Future outlook. The large supplies of ore which are known to exist, the improvements in the methods of extraction, and a multitude of new uses make the outlook for the aluminum industry promising indeed. The tremendous expansion of the aircraft industry and the demands for strength, speed, and lightness in transportation equipment on land and sea seem to assure rapidly expanding products now and in the future.

Lead

The properties which make lead valuable are its softness, malleability, and resistance to corrosion. It can easily be rolled or hammered into sheets but, unlike copper or iron, it lacks ductility—that is, it cannot be drawn out into fine thread or wire. Its resistance to corrosion makes it exceptionally valuable for plumbing fixtures, storage batteries, and for cable, so widely used in the telephone and telegraph industries. Since lead is the only one of the common metals which is unaffected by sulphuric acid, it is used in construction of linings of all kinds of apparatus used in the manufacture of this important industrial chemical.

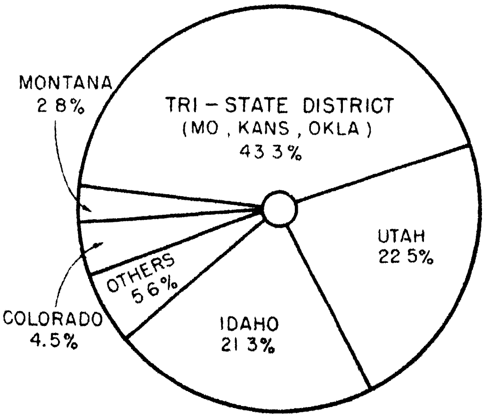
Large amounts of lead are converted into white lead, red lead and litharge pigments, which are widely used in paints because of their high covering power and their resistance to weathering. During recent years more lead has been used for pigments than for any other purpose, with cable covering for electrical purposes easily in second place, followed in third place by its use in storage batteries. These are followed by numerous other uses which are less in quantity but nevertheless of great importance in modern life, such as solder, type metal, foil, collapsible tubes, chemicals, insecticides, and a host of others. In 1946 the percentages of lead used to meet major industrial demands were 32 per cent for paint pig-



World map of principal centers of production of lead and zinc. Prominence of centers is indicated by the size of type used to designate them.

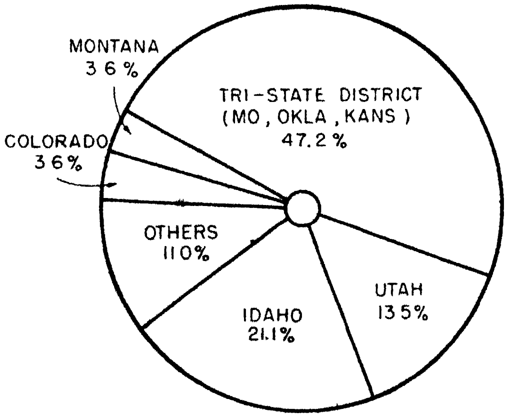
ments, 13 per cent for cable coverings, 11 per cent for storage batteries, 9 per cent for tetraethyl fluid, 6 per cent for solder, 5 per cent for pipes, traps, and bends, and 5 per cent for sheet lead. Smaller percentages were used for numerous other purposes. These various uses help us to understand the importance of lead in modern industry. For many of them there are no satisfactory substitutes, and therefore the lead-producing countries find a ready world market for their output.

Geographic distribution of lead ores. The most important lead ore is a chemical combination of lead and sulphur known as *galena*, which, when pure, contains 86.4 per cent of metallic lead. It can readily be recognized by its weight and its tendency to occur in regular, cubic crystals. As mined,



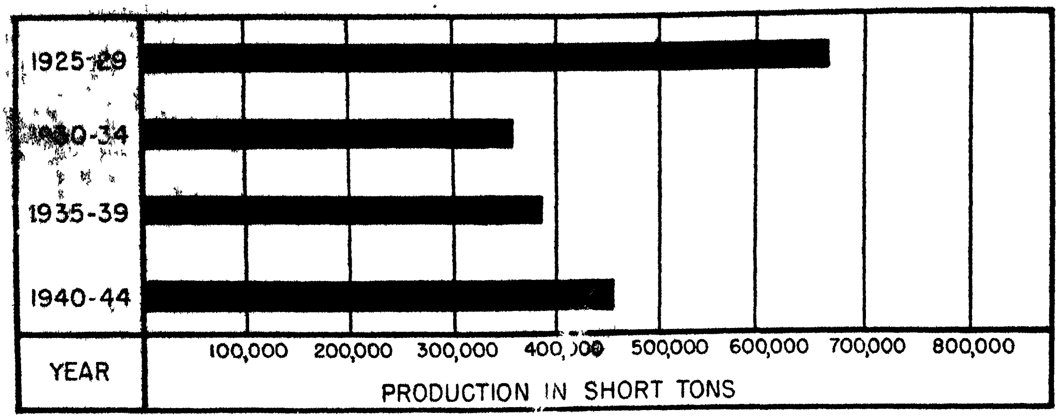
(A.)

Lead. Average annual mine production of recoverable lead by principal districts, 1924-1929.



(B.)

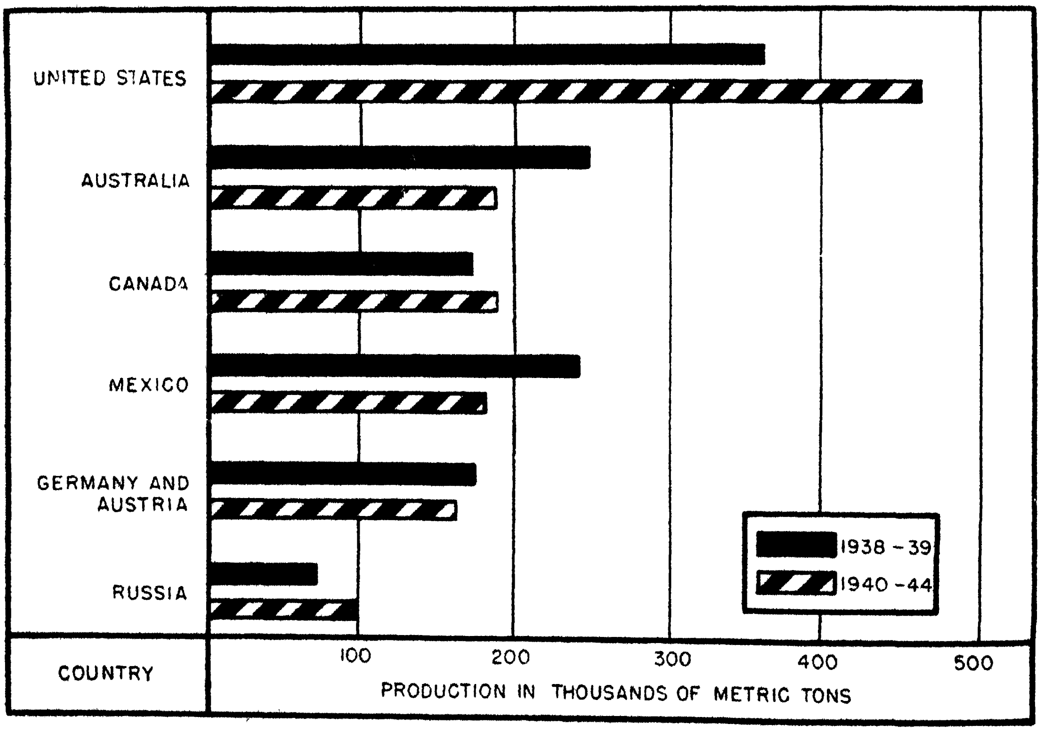
Lead. Average annual mine production of recoverable lead by principal districts, 1941-1945.



(A.) Lead. Average annual mine production of recoverable lead in the United States during the 5-year periods indicated. Note that quantity of production even during World War II did not reach figures as high as were attained in 1925-1929.

however, *galena* is associated with impurities and with other metals, thus reducing seriously the metallic content of the lead in the ore.

Lead ore is widely distributed; every continent seems to have some deposits of potential value (see Illus. below). The foremost producing centers outside the United States are in Canada, Mexico, Germany, Spain, and Australia. The United States



(B.) Lead. Average annual world production of leading countries during the prewar and war years. What important shifts in production appear to be evident?

in recent years has smelted from 20 to 25 per cent of the world's lead, although in earlier years its share was even larger.

Lead output of the United States. In the United States the foremost lead-producing center is in southeastern Missouri, where mining has long been in progress. Ranking next in importance to southeastern Missouri is the Coeur d'Alene region of Idaho. Third place as a center of production is in southwestern Missouri and in the adjacent sections of Oklahoma and Kansas, where considerable quantities of ore have long been produced in the area ordinarily referred to as the Tri-State region. Other centers of high production are in the Bingham and Park City districts of Utah; smaller centers have long held considerable prominence in Montana, Colorado, and Arizona.

The total output of refined primary lead in the United States in late years has fluctuated from a high mark of 580,000 short tons in 1942 to 338,000 short tons in 1946, and a moderate post war recovery to 387,000 short tons in 1948. The fluctuations in mine production of recoverable lead are graphically depicted in Illus. A, p. 468, wherein the conditions prevailing during the boom period of the late twenties stands out in sharp contrast to the depression of the early thirties. It should also be noted that the war years, 1940-1944, failed to equal the 1925-1929 period. The failure to induce sharp expansion of lead output in the United States under the demands of World War II appears to indicate reduction of readily available reserves, a condition that seems to be world wide.

Lead output of foreign countries: MEXICO. The production of lead in Mexico has varied greatly during the past thirty years. Prior to 1913, under a stable but despotic government the country had become an important producer. Because of the unsettled conditions which then set in, production declined to a very low level in 1916. Since that time the trend has been upward, and Mexico has taken second place among the countries of the world with output generally ranging from 140,000 to more than 200,000 tons per year. At the present time, the second place in any one year may be taken by Mexico, Australia, or Canada. The lead industry of Mexico is financed in large measure by American capital and a large percentage of the exports are sent to the United States.

CANADA. The lead output of Canada increased steadily during the prewar years but made little additional advance during World War II (see Illus. B, p. 468). The greater part of the production is in British Columbia, which accounts for approximately 95 per cent of the total output of the Dominion. Small quantities of lead are produced in the provinces of Nova Scotia and Ontario. Canada has the advantage of large capital resources from Europe and the United States and of intimate commercial relations with the other parts of the British Empire. Furthermore, cheap power is available in the producing areas, a factor highly favorable to the mining and smelting operations. Ore reserves which appear to be sufficient to produce lead at the rate of 180,000 tons per year for 25 years are claimed to have been proved. If further exploratory work should demonstrate this to be the case, Canada will undoubtedly hold its place as one of the great lead-producing countries.

AUSTRALIA. Australia has been an important lead producer for a number of years and has recently vied with Mexico and Canada for second place among lead-producing nations. The output declined during the war years (see Illus. B, p. 468) and the trend continued downward during the early postwar period. There seems no question that ample ore reserves exist, the principal ones having been reported in Queensland and in the Broken Hill area of New South Wales. Australia seems assured of permanent importance in lead production, but it appears unlikely that any largely increased output will occur in the near future because of the difficulty of competing with the production centers located closed to the great industrial areas. World demand is increasing so rapidly that competition with other producing centers may not continue to be significant.

GERMANY. Germany has the distinct advantage of having an abundant supply of fuel for smelting and refining and, under ordinary peacetime conditions, she holds a highly favorable trade position in European markets. Cheap fuel, nearness to centers of consumption, splendid transportation facilities, and efficient marketing organizations are advantageous factors. Smelter production of lead in Germany and Austria was greatly expanded during the prewar years under the pressure of increasing armament and for general industrial purposes. From about 100,000 tons of smelter production in 1929, Germany's output increased to 179,000 tons in 1939. Unsettled postwar conditions served to discourage and almost destroy the lead-smelting industry. While this period of disaster was followed by gradual increase in output of lead, the trends of the near future can hardly be forecast because military control and political policies are certain to be controlling conditions during the years immediately ahead.

SPAIN. (See Illus. p. 467). The lead mines of Spain have been operated for a long time and costs are such that when world prices are low production at a profit appears impossible. As a result of inability to meet competition in the large world markets, the production of lead in Spain has shown a slow downward trend, a trend which was accelerated by internal strife and the general economic conditions resulting therefrom. In the years preceding 1940, Spain contributed only a few per cent to world smelter production; but during the war period, under the incentive of high prices, output was nearly doubled. After 1941 the decline was sharp—from 47,000 metric tons to 31,000 metric tons—while at present it appears to be fairly well stabilized.

International trade. On the whole, the New World is the principal source of lead exports and the Old World is the principal market. Europe produces less than one-half of the lead it needs and therefore depends upon outside sources for supplies to make up the deficiency. Ordinarily the United Kingdom is the foremost foreign market for lead exports from the United States, and it is followed closely by Germany, France, and Japan.

Inasmuch as the uses of lead are so universal in the industrial world that no country can dispense with this metal, the present situation in foreign trade is not likely to undergo any radical change in the near future. However, in this summary, as in the case of the other important metals, the status of the Soviet Union cannot be given with any assurance of accuracy. It is believed that Russia has large and important stores of lead ore and that she is making rapid progress in mining, smelting, and refining, and also in the manufacture of the numerous products into which lead enters. The dearth of statistical material is impressive, particularly in view of the fact that other nations publish their output and even their estimates of reserves, thus making them available to the Soviet Union in common with the rest of the world.

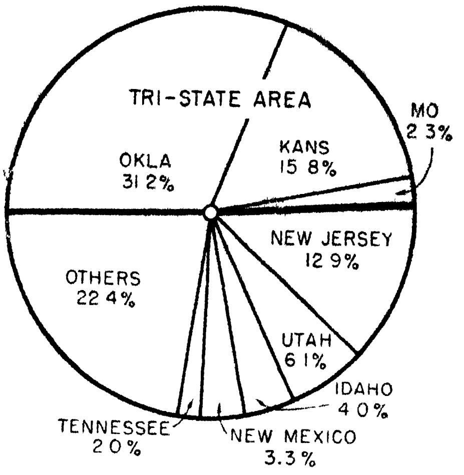
Zinc

Zinc is a soft, white metal with a melting point of about 788°F. and a boiling point of 1680°F. Although brittle at ordinary temperatures, it becomes malleable at about 250°F. and can be rolled into sheets at that temperature. Because of its low boiling point, special processes of smelting the ore had to be devised to capture the fumes of metallic zinc and condense them into solid metal. Zinc ore, like copper ore, depends on coal for smelting and upon low-cost electric power for refining.

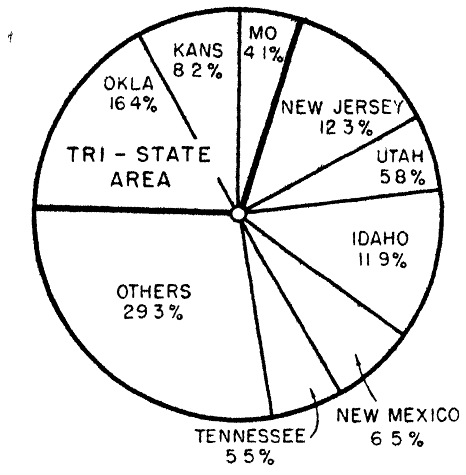
Zinc occurs in a wide variety of minerals, but the ores of commercial value are chiefly sulphides, of which sphalerite (ZnS) is the most important. Most sphalerite ore contains from 4 or 5 to 20 per cent zinc and must be concentrated by gravity mills or flotation processes before it is ready for the smelters.

The properties which make zinc particularly valuable are its resistance to oxidation, its malleability, and its chemical properties, which give it high place in the manufacture of numerous alloys and pigments. In the United States zinc is used principally for making brass, galvanizing, zinc base alloy, and rolled zinc. For the period 1940-1946, 38 per cent of the zinc consumption was used for brass, 36 per cent for galvanizing, 14 per cent for zinc base alloy, and 9 per cent for rolled zinc.

Galvanizing is a process of covering sheet iron or steel with a thin coating of zinc; iron sheets so treated resist rust, and thus their life is greatly prolonged. Brass is an alloy of zinc and copper in various proportions, but ordinarily it consists of from 66 to 83 parts copper and 34 to 17 parts zinc. Zinc enters largely into the manufacture of electric batteries, imitation gold, and so-called German silver. Furthermore, chemical compounds of zinc are used in the manufacture of paints and rubber tires and also as preservatives of wood.



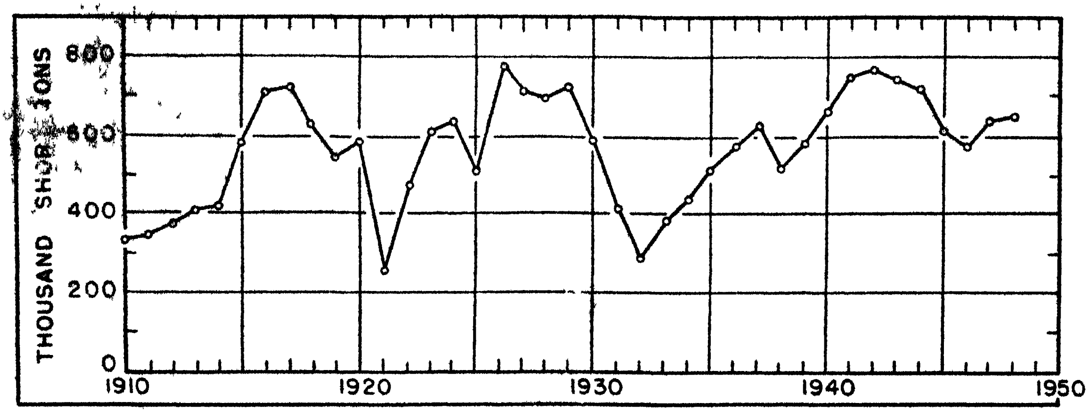
(A.) Zinc Average annual mine production of recoverable zinc in terms of percentages by areas and states, 1925-1929



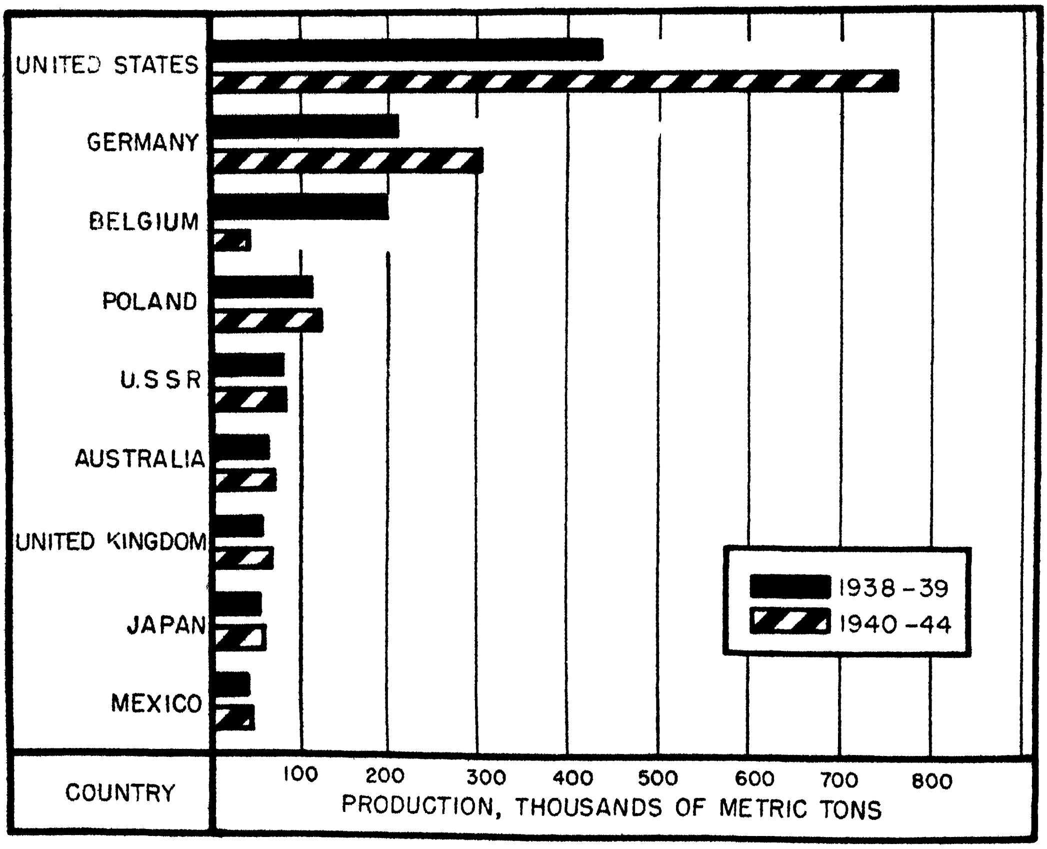
(B.) Zinc. Average annual mine production in terms of percentages by areas and states, 1941-1945. What important change is noted in the Tri-State area? Which of the western states have increased their percentage position in marked degree?

Geographical distribution of zinc ore. Sphalerite, when pure, contains about 67 per cent metallic zinc. It is often associated with ores of other metals, especially lead, and many of the zinc-producing districts of the world practically coincide with lead districts (see Illus. p. 467). Although zinc mining is scattered widely over the world, the largest part of the output is furnished by a comparatively small number of places, with the United States producing ordinarily up to 40 or 50 per cent of the total.

Zinc output of the United States. The Tri-State district, embracing northeastern Oklahoma and the adjacent parts of Kansas and Missouri along the margin of the Ozark uplift, has for some time been the foremost center of zinc mining in the United States, producing up to 40 per cent of the output of the entire country. Joplin, Missouri, is often referred to as the "Zinc Capital of America." Zinc ores almost free from lead occur in New Jersey, the principal zinc-mining state of eastern United States, and this district, whose yearly output has given the state second place for a number of years, is an exception to the prevalent association of zinc ores with those of lead.



(A.) Zinc. Annual mine production of recoverable zinc in the United States since 1910. Account for the high points in the curve and also the low points.



(B.) Zinc. Average annual world smelter production by principal countries, 1938-1939 and 1940-1944. What reasons may be suggested for the slight increase in production shown by a number of the countries during the war period? How does one account for the marked decrease in smelter production shown by Belgium?

In the Rocky Mountains, zinc is found in complex ores which also often contain lead, silver, manganese, and gold. Idaho, Utah, Montana, and Arizona are the states leading in production in this area. In recent years, Idaho has increased its output rapidly and has taken first place, while in Oklahoma persistent decline since 1941 reduced that state to fifth place in 1948.

The annual production of metallic zinc in the United States during the past decade has ranged from about 450,000 tons to a maximum of 768,000 tons. The Tri-State district, New Jersey, Idaho, and Utah are the outstanding producers of recoverable zinc from mining output. The trend in recent years has been marked by decline in the Tri-State district and increase in the western states.

Foreign production. In recent years Canada has ranked second in output and thus has become established as one of the large zinc producers among the nations of the world. The bulk of the production is derived from British Columbia and the Flin Flon region north of Lake Winnipeg. While the extent of the ore resources is not well known, it is believed that large reserves exist and that Canada can sustain an annual output of 200,000 tons for some years. See map on p. 467.

Mexico's output of zinc is largely derived as a by-product from the lead-silver mines of the country, and it seems probable that a yearly production of 30,000 to 50,000 tons may be expected during the years ahead. Fluctuation will probably depend largely upon changing industrial activity abroad, as well as within Mexico.

In Europe, zinc ore is mined on a fairly large scale in Poland, France, Germany, Yugoslavia, Italy, and some other countries. The outstanding center was in Upper Silesia, a district in southeastern Germany and southwestern Poland.

Belgium is usually credited with a large output of metallic zinc, most of which is derived from imported ores and concentrates. The total output of zinc from the Belgian furnaces has approximated 6 per cent of the world's total in recent years. Belgium is well located as to markets, well supplied with fuel resources, and well provided with mechanically skilled labor.

These factors, considered together with the existence of an old and well-established refining industry based originally upon the ores of the Moresnet region of northeastern Belgium, have led to the development of a great refining industry which draws upon the ores from many countries for its raw materials. In recent years Italy, Australia, and Mexico have furnished a large portion, and even the United States has contributed by furnishing concentrates to be refined and milled in Belgian plants.

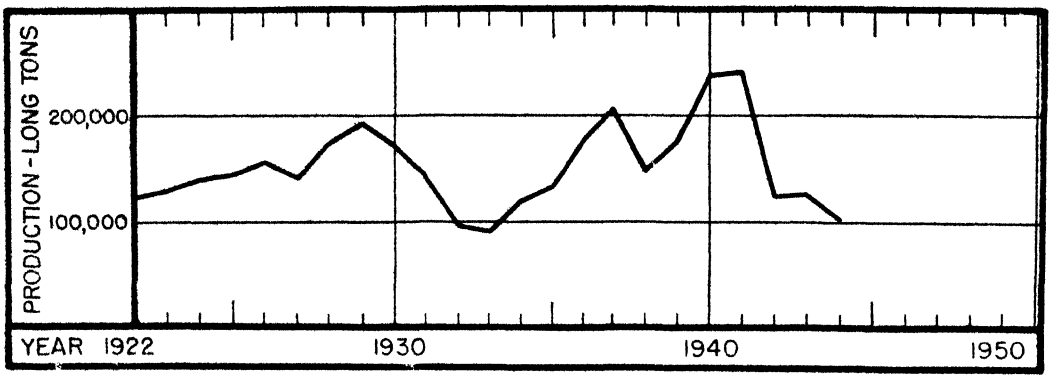
In Germany, the principal zinc production occurs in Upper Silesia. The statistical position of the country was impaired when the smelting and refining plants were granted to Poland at the close of World War I. Thus, the control of marketing the zinc passed out of the hands of the German producers and zinc ores had to be exported from German Silesia to the neighboring Polish smelters until German-owned smelters could be erected. The smelters of western Germany are supplied partly by imported ore. The future is clouded by political uncertainties which may not be resolved for several years.

During the past decades Poland has been credited with about 7 per cent of the world's zinc production (see Illus. B, p. 472). Considerable amounts of American capital were invested in the Polish works, and modernization of smelters was undertaken in order to increase their capacities and bring about greater economy of operation. After World War I, Poland faced the handicap of having to take over smelters without having full control over the ore reserves necessary for their successful operation. However, with the aid of American and other foreign capital, it became possible to introduce modern improvements. With imports of ore, mostly from Germany, to supplement the domestic production, the zinc industry was kept running at a profitable level.

France is credited with substantial

smelter output but produces virtually no zinc ore within her own borders. Her smelters are reported to have a potential capacity of 90,000 tons per year, but they have operated on a part-time basis with an actual output of 20,000 to 30,000 tons. The ore is imported from Mexico, Spain, Turkey, Sweden, and other sources.

During the prewar years, 1935-1939, Italy produced considerable zinc ore for export because her mine production greatly exceeded her smelter capacity. Ore was shipped to Belgium, Poland, France, and Germany. Mining activities, severely disrupted by World War II, are gradually being resumed, and the trend of output may be expected to continue upward at a moderate pace until the prewar status is reached.



Tin Annual world mine production since 1922

The United Kingdom maintained a smelter output of 60,000 to 70,000 tons of zinc throughout the war years. The early postwar period maintained about the same output, largely on the basis of imports of ore, and the trend appears to be quite stable. There seems little likelihood of any pronounced change during the years immediately ahead.

Other centers of zinc production. The principal zinc-mining center of Australia is near Broken Hill, New South Wales (see Illus. p. 467). Australia lacks close contact with world markets and hence feels keenly the competition of the more readily available supplies of North America and Europe. This remoteness and the lack of easily accessible high-grade fuels are serious drawbacks to the development of the zinc resources of that country.

In the case of zinc, as with most other important mineral resources and industries, information concerning the status of operations and of known reserves in the Soviet Union is lacking. However, that some exploitation is in progress and that reserves of zinc ore exist are well-known facts. Estimates of reserves thus far made can at best be classified only as guesses meagerly supported by actual information. It is to be expected, however, that if and when the iron curtain is lifted the Soviet Union will probably emerge as a country self-sufficient in its production of metallic zinc and its products, and with reserves sufficient to support the industrial requirements of the nation.

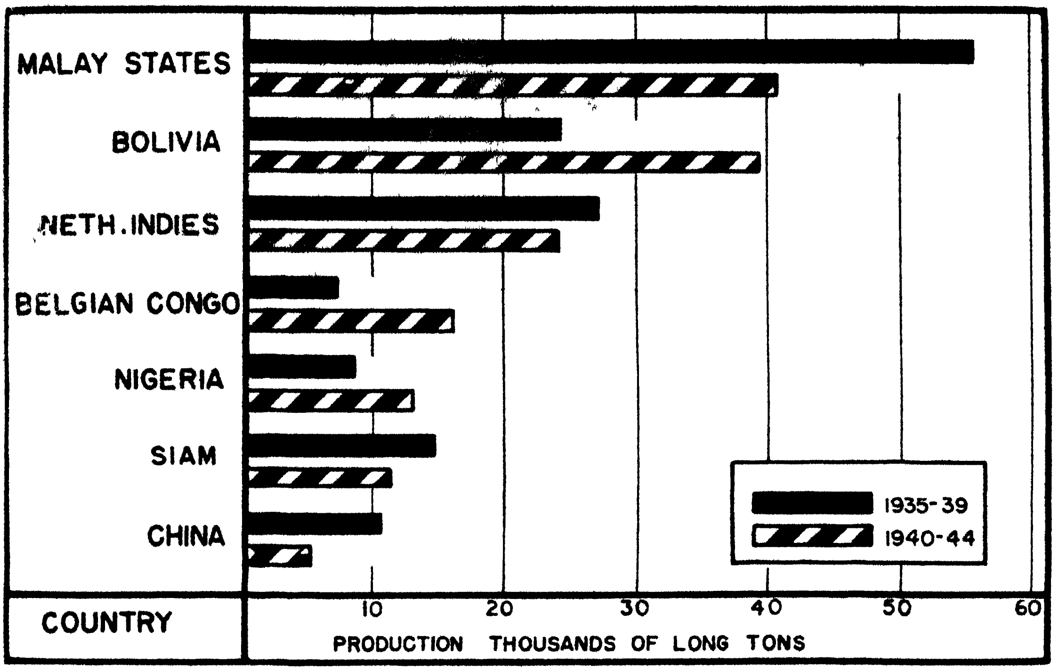
Tin

For many centuries, tin was prized because when fused with copper it made bronze, a metal then greatly in demand. Several centuries before the dawn of the Christian era tin was mined in the Cornwall district of southwestern England. The importance of this district, long the chief source of the world's tin, is indicated by the fact that careful students have estimated its total output from 500 B.C. to A.D. 1800 at about 2,500,000 tons. Another important source of tin for many centuries has been the finger-shaped peninsula of southeastern Asia known as Malaya. It is estimated that more than a million tons of tin were obtained from this source before 1800. Until comparatively recent times, Cornwall and Malaya furnished nearly the entire tin supply of the world.

Since 1800 the production of tin has been expanding at an increasing rate. During the past twenty-five years about as much tin has been mined as during the entire preceding one hundred years, a convincing index of its increased usefulness in the industrial arts of the world.

Present uses of tin. The uses of tin are based largely on its resistance to rust and decay. It is affected but slightly by air or moisture, and it is so resistant to many acids, both organic and inorganic, that it enters extensively into the manufacture of tin plate for a wide variety of usages ranging from food containers to metal roofs. It is used also in the manufacture of solder, bronze, type metal, babbitt metal for bearings, and tinfoil for collapsible tubes.

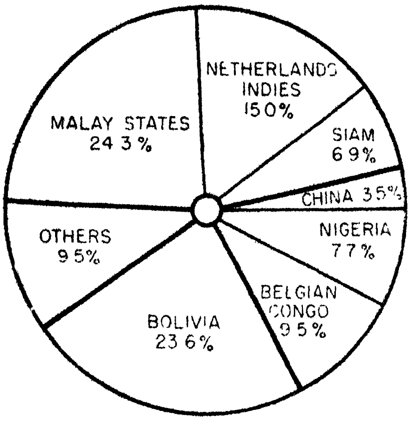
The growing use of tin plate in the manufacture of tin cans for preservation of foods has been an important factor in the growth of the tin industry since 1900. At first the method of preserving foodstuffs in tin cans won favor slowly because people thought that there was danger of poisoning through the corrosion of the metal. As a matter of fact, the spoiling which occurred in canned products was due to poor methods of canning and sealing the cans, and not to any fault of the tin. Another handicap was the cost of the cans. Until the invention of the stamp machine by Allen Taylor in 1847, the making of cans was a hand industry, and the best tin worker could make only about sixty cans a day. This has been changed



Tin. Average annual world mine production, 1935-1939 and 1940-1944. How account for the decrease in production indicated for China and Siam in contrast with the increase shown for most of the countries during the war period?

so that tin cans are now made rapidly and at amazingly low costs. With machine methods of manufacture as well as of canning and sealing, and with increased knowledge of the limits of safety connected with this mode of food preservation, the entire tin industry has felt the spur of rapid progress.

Tin plate is made by coating steel sheets with pure tin, the practice being to use about one pound of tin in making 200 square feet of tin plate. Another important use is in the manufacture of *terneplate*, similar to tin plate except that the coating consists of an alloy of lead and tin instead of pure tin. Terneplate is used for roofing, for gasoline tanks for automobiles, and for other nonfood containers. In the United States, the manufacture of the two products, tin plate and terneplate, accounts usually for over 40 per cent of the virgin tin consumed annually.

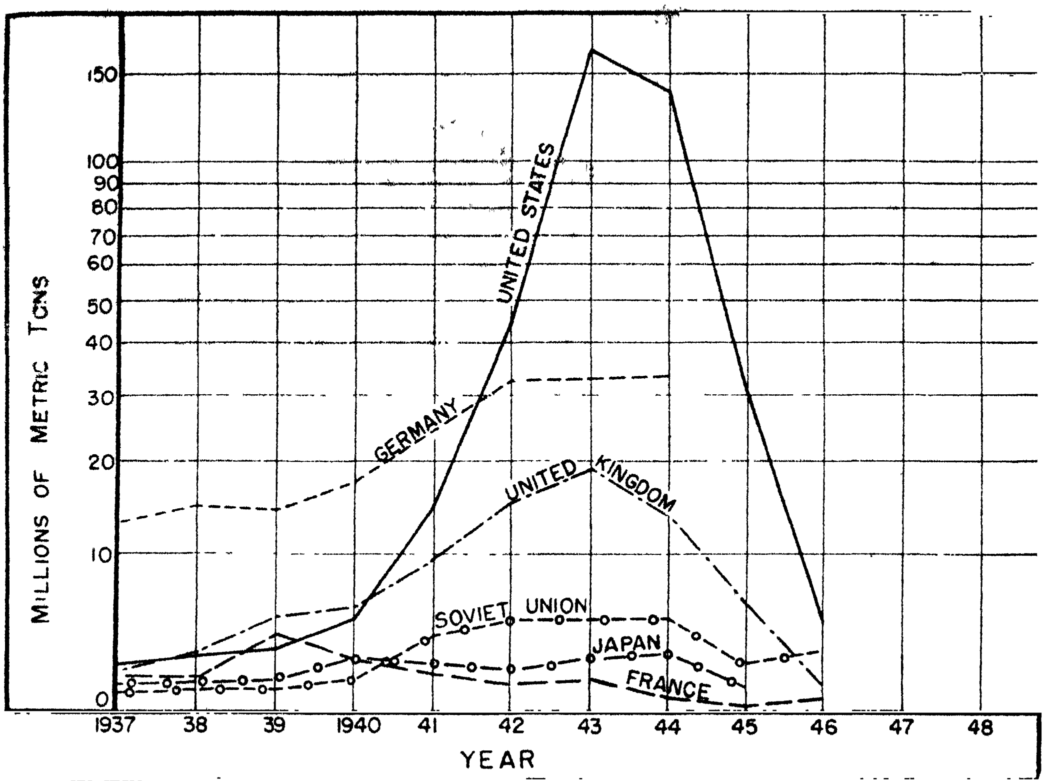


Tin Average annual mine production during 1940-1944, expressed in percentages of the world total, by principal producing countries. What three countries rank highest in mine production of tin and what three centers of tin production may be said to characterize the world picture?

The world's sources of tin. Tin is a comparatively rare metal, a fact which many overlook because of the cheapness of tin plate and the resulting extensive use of tin cans. The annual world output of tin varies from 140,000 to 200,000 metric tons, a small quantity in comparison with that of zinc and lead, each of which ordinarily exceeds 1½ million tons. The bulk of the world's supply is furnished by the mines of three centers: the Malay States, the East Indies, and Bolivia. A few other areas produce tin in sizable quantities and have prospects of further increasing their output; this is particularly true of the Belgian Congo, Nigeria, Siam, and China, where fairly large bodies of tin ore have been reported to exist but where exploitation has not yet been pushed vigorously (see Illus. p. 475). Cornwall, the ancient world center, now produces less than 1 per cent of the world total, and there seems little probability of any improvement in its position. The United States is almost lacking in tin or tin ore and therefore is dependent entirely upon foreign sources for its supply. This dependence is keenly felt because the country consumes far more tin per year than is true of any other country in the world.

Most of the ore mined in Malaya and in the East Indies is reduced to metallic form in smelters in Singapore and on the Island of Banka, whereas the ores mined in Nigeria are concentrated near the mines and are then shipped to smelters in Liverpool and Redruth, Cornwall, England, to be converted into refined tin. Through ownership and operation of the smelters, the production of primary tin is controlled almost entirely by British and Netherlands capital interests. In this country a large new tin smelter has been erected and is in operation in El Paso, Texas, to take care of Bolivian and such other ores as may be sent to it for conversion into refined tin.

Outlook for the future. The decade 1935-1945 was marked by two distinct phases of activity, prewar and war. Since tin is an essential in the manufacture of war machinery and munitions, the requirements of the western world upon its one dependable source were heavy, a fact depicted on pages 474 and 475. The sharp increase in production and percentage shown by Bolivia is readily explained by the needs, particularly of the United States, and this was similarly true of the requirements of the British for the tin produced in Nigeria and the Belgian Congo.



Magnesium. Annual production by the six leading producing countries of the world. During the prewar years what country ranked foremost in production of magnesium? What trend in production seems to be characteristic of all the producing countries?

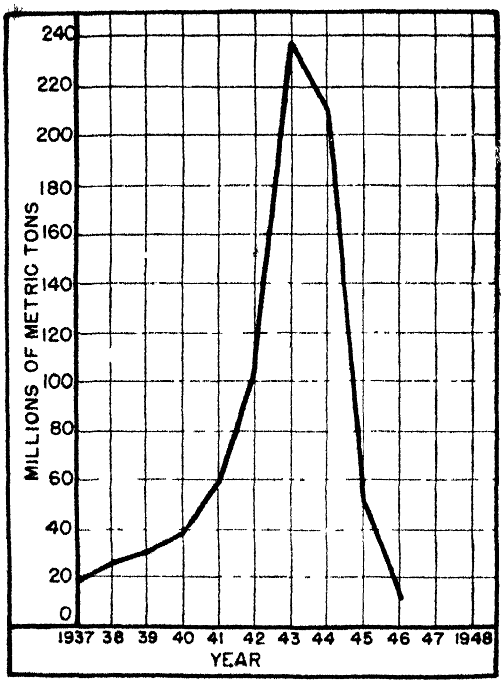
Prospecting during the past two decades has indicated possibilities of important tin ore bodies in Africa, the Soviet Union, and Argentina. That further exploratory work will be pushed vigorously whenever market conditions warrant seems assured, and valuable reserves may be found; but for many years to come British Malaya and the western islands of the East Indies will probably remain the foremost source of primary tin. In Africa, exploitation in Nigeria and in the Belgian Congo seems to promise continued substantial output. In the Western Hemisphere, Bolivia appears certain of maintaining its leadership for the foreseeable future, and the output will probably continue to be an important source of supply for the United States. On the whole, therefore, in the light of present knowledge, there appear to be three great centers of tin output: Malaya and the East Indies in the premier position, followed by the more newly developed deposits of Africa and the comparatively stable output to be expected from Bolivia. There does not appear to be any probability of change of leadership either in centers of output or in capital control for some time.

Magnesium

Magnesium is the lightest and youngest of the structural metals. It is described chemically as an element of silvery white appearance with specific gravity about one-fifth that of copper and only two-thirds that of aluminum. It was first derived as a pure metal by Robert Bunsen, a German chemist, in 1852, and its early development on an industrial basis occurred in Germany as a by-product of the potash industry. Its properties of burning readily and giving off brilliant light made it valuable in photography and other chemical industries.

Although magnesium is recognized as the *third* most common industrial metal, exceeded only by iron and aluminum, not until recently was it possible to separate from its compounds except at high cost. As the qualities of magnesium became more fully understood and its importance as a light metal for alloys and as an illuminant for flares and tracer bullets became appreciated, huge sums were spent for research and for technical processes by which mass production at low cost could be made possible. How well this paid off is shown by the price changes. During World War I magnesium sold at $5 per pound; in 1928 the price had dropped to 55 cents per pound, and during World War II the price was pegged at 20½ cents per pound in the United States.

Occurrence of magnesium. Magnesium is a component of a number of minerals and rocks, and it occurs as a chemical compound in sea water. Magnesite is a carbonate of magnesium, which is of wide distribution and is used in furnace linings as a refractory, that is, as a resistant to fusion under high temperatures. Dolomite, a lime-magnesium carbonate, is a rock from which magnesium is derived at moderate expense. The stores of dolomite over the world are so abundant that scarcity need never be feared. The newest development is that of obtaining magnesium by treating ocean waters, and huge plants have been built and placed in operation at Freeport and Velasco, Texas. In ocean brines it is reported that 4 out of 1,000 parts consist of magnesium chloride. That implies, of course, that tremendous quantities of water must be treated in order to obtain sizable quantities of metallic magnesium. Methods of extraction and refining were devised whereby from these several sources the production of magnesium in the United States expanded at a phenomenal rate during the early years of World War II to a peak of 183,584 tons in 1943 (see Illus. p. 477).



Magnesium Graphic illustration of world production since 1937 In view of newly discovered uses for which magnesium seems to be adapted, what change in trend may be expected to follow 1946?

Uses of magnesium. Although brittle and of little use directly for structural purposes, magnesium as an alloy with aluminum, zinc, and other metals adds strength with low weight. The principal uses of magnesium as a metal during wartime was for flares, incendiaries, powder, and chemicals. In general, these uses taken collectively constitute less than 50 per cent of the total magnesium consumed, and in some years less than 25 per cent of the total. Structural products are made up of alloys of magnesium and aluminum, zinc, and other metals, and consist of such materials as sheet metal, tubing, rods, castings, and structural shapes. The most important uses of the magnesium alloys are in the manufacture of aircraft where light weight combined with strength constitutes the very essence of success in construction. Other uses are in the manufacture of automobiles, railway cars, buildings, and furniture of various kinds. Since sources of supply are virtually inexhaustible, progress in use will depend upon development of skill and economy of output in competition with other available materials.

During the war years, 1942-1945, magnesium shipments comprised 44 per cent for production of aircraft, 34 per cent for incendiaries, 12 per cent for other military uses principally tracer and incendiary ammunition, and the remaining 10 per cent largely for aluminum alloys. In the year of highest plane output, 1944, when heavy planes were dominant, the records show that as a general average more than half a ton of magnesium was used in the construction of each plane.

Production of magnesium in the United States. The production of magnesium in the United States made a feeble beginning in connection with World War I but reached an output of only 142 short tons in 1918. During the following decade production was almost nil; but during the 1930's, under the incentive of new techniques, production began a slow rise to 3,350 tons reached in 1939. Then, however, war demands for military equipment from flares to planes, supported by security measures sponsored by the federal government, induced unprecedented expansion to the 183,584-ton peak in 1943 (see Illus. p. 477). With reduced military needs, the decline during the following three years was almost as precipitous as the rise following 1939. The curve of production from 1937-1946 is evidence of the significance of magnesium as a war resource but not as a resource useful in peacetime.

To meet the need for strength and light weight so characteristic of transportation on land and in the air, magnesium promises to serve a highly useful purpose. The quality of the metal and its alloys is being improved steadily as research reveals the causes and conditions that betoken weakness. With improved methods of production and techniques of manufacture for greater strength and efficiency, magnesium seems certain to rise to prominence as an industrial metal in this country.

Magnesium in foreign countries. The curve of world production shows the same characteristics as does the curve for the United States, and for the same reason (see Illus. p. 478). Magnesium thus far has been largely a war metal. Germany, early preparing for war, dominated the world output until war became a reality in 1939 and even during the first two years of the world conflict produced nearly one-half of the world total (see Illus. p. 477). Statistics as published for the Soviet Union are but guesses, possibly intelligent guesses, but one wonders how nearly accurate they may be.

Outlook for the future. As efficiency of transportation increases, the demand must center upon light weight without loss of needed strength just as emphatically as it has upon engine efficiency to date. Metallurgy will bear the responsibility of research to learn how to improve the quality of metallic magnesium and of its alloys. Engineering faces the responsibility of learning and applying the "know how," the skills necessary to make use of the truths discovered through metallurgical research. On this basis we may have confidence that the boundless ocean will contribute out of its abundance magnesium to make better living on the land and more efficient transportation through the air.

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Chapter Twenty-seven

THE DEVELOPMENT OF INDUSTRIAL REGIONS

VERY FEW OF THE THINGS THAT WE consume or use are produced by Nature in the form in which we use them. The cotton, wheat, petroleum, and ores that have been discussed in the preceding chapter would be of little use to us in their original forms. Not until the cotton has been spun into thread, woven into cloth, and cut and sewed into clothing can we get dressed in the morning. Not until the wheat has been ground into flour and baked into bread can we have toast for breakfast. The processes by which raw materials or partly finished materials are converted into more usable forms are known as *manufacturing*. Like other industries that create "form utility," such as agriculture, mining, and forestry, manufacturing involves the application of labor and capital to natural resources.[1]

Importance of manufacturing. Manufacturing is the leading industry of the United States and its prominence is still increasing. It produces about one-fourth of our national income and employs about one-fourth of the workers. In his state-of-the-union address to Congress in 1949, the President of the United States said: "Since the boom year of 1929, while our population has increased by only 20 per cent, our agricultural production has increased by 45 per cent, and our industrial production has increased by 75 per cent." The accompany-

TABLE XIII

NATIONAL INCOME OF THE UNITED STATES, BY INDUSTRIAL ORIGIN
(net value added, in millions of dollars)

	1929	*1933*	*1939*	*1946*
*Manufacturing	22,012	7,563	17,936	47,653
Trade, wholesale and retail	13,090	5,375	12,126	32,811
Government and government enterprises (federal, state, local)	5,114	5,349	8,550	23,019
*Agriculture, forestry, and fishing (all but 2% from farms) .	8,002	3,521	6,120	18,549
Service. . . .	10,168	5,447	8,080	17,020
Finance, insurance, and real estate . .	13,098	5,681	8,216	14,753
Transportation	6,562	2,958	1,543	10,202
*Contract construction . . .	3,691	735	2,254	6,063
Communications and public utilities. . . .	2,878	2,000	2,863	4,747
*Mining	2,097	662	1,601	3,118
From rest of the world . . .	643	293	243	239
Total . .	87,355	39,584	72,532	178,204

Source: *Statistical Abstract of the United States, 1948.*

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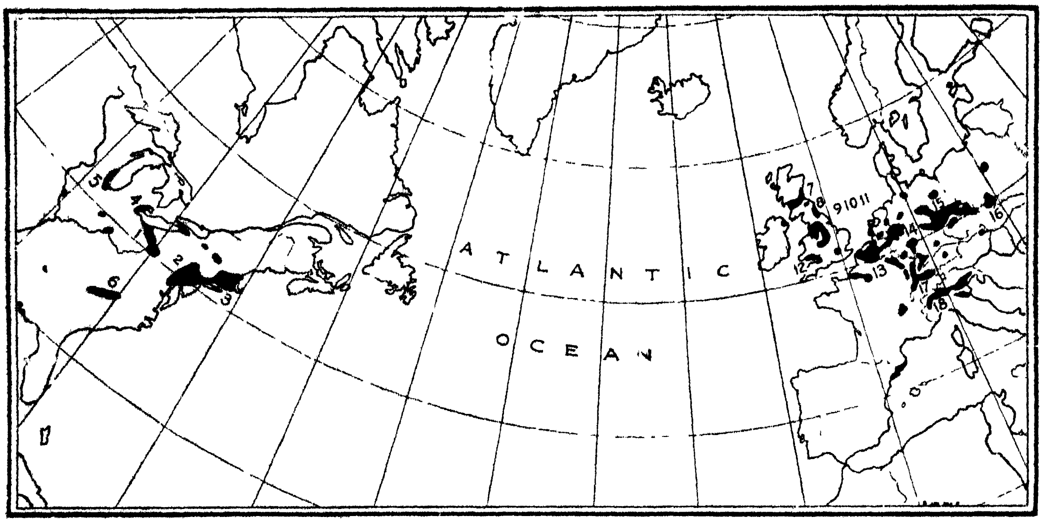
[1] The term *industry* is often used to denote manufacturing; the U. S. Census Bureau and many economists use it to denote any occupation, including even agriculture.

ing table expresses the relative rank of each of the broad occupation groups of the United States in certain years in terms of value added by each group rather than in terms of physical output.

The starred groups in the Table are the ones devoted primarily to the production of form utility. At the time of the 1940 census, 48.7 per cent of the gainfully employed people of the United States fourteen years old or older were in these basic industries: manufacturing, 23.4 per cent; agriculture, 18.5 per cent; construction, 4.6 per cent; mining, 2.0 per cent; and forestry, 0.2 per cent.



Principal industrial districts of eastern United States and western Europe.

1. Pittsburgh-Wheeling-Cleveland
2. New York-Philadelphia-Baltimore
3. Southern New England
4. Detroit
5. Southern Lake Michigan
6. Southern Piedmont
7. Scottish Lowland
8. Newcastle
9. East Pennine
10. Midlands
11. Lancashire
12. South Wales
13. Northern France-Belgium
14. Ruhr
15. Saxony-Bohemia
16. Silesia
17. Swiss Plateau
18. Northern Italy

In the other industrial countries of the world the preponderance of manufacturing is similar to that in the United States. Exact comparison of figures is not possible, because of differences in census definitions of "manufacturing"; many countries, for example, include construction and transportation industries, whereas others do not. Just before the war, the percentages of workers employed in the manufacturing and mining industries were as follows: England and Wales, 48.2 per cent; Germany (old boundaries), 40.6 per cent; France, 35.1 per cent; Italy, 28.7 per cent; and Australia, 36.3 per cent.

In view of the importance of the manufacturing industry in the life of the individual and of the world, geographic questions such as the following are of vital interest: Where are the principal manufacturing areas of the world situated? Why did they develop in these places? What differences are there in the locations of different industries? What changes are occurring in the location of industries? The following pages will deal with such questions.

The bases of world industrial location. A glance at a map such as that shown above reveals at once the uneven and spotlike distribution of manufacturing districts. The distribution pattern is an orderly one, not developed haphazardly as it might appear at first glance. A reference to maps showing distribution of population and of coal (pages 16 and 366) indicates that manufacturing has some regional relationships with natural resources and cultural phenomena. These relationships have varied in the course of time.

In the period before the widespread use of power-driven machinery, when small-scale industry conducted on a handicraft basis was the rule, manufacturing could be carried on profitably even in small communities, and it depended chiefly upon local availability of raw materials or proximity to a port through which raw materials could be obtained from a distance. When water power came into use for operating machinery, streams with modest falls became favored sites for industry. With the advent of mineral fuel as the chief source of power, regional manufacturing enterprises attained their present-day status.

Even today, however, much of the world's population still is on a handicraft manufacturing basis, notably in China, southeastern Asia, Africa, and large tracts of South America. The United Nations, Department of Economic Affairs, reported in 1948 that there is a universal desire on the part of the underdeveloped countries to increase their industrialization so as to increase their national incomes by processing their own raw materials and, in some instances, to make themselves less dependent upon outside sources in case of wars.

The industrialized countries, too, feel the need for further development of their manufacturing: in Europe, because of war devastation of factories, and in the United States, because our productive facilities have not kept pace in all fields with our people's wants and with our desire to help supply Europe's deficiencies. The Economic Report of the President in 1948 stressed that in this country the reserve capacity of many of our basic industries, such as petroleum refining, steel, electricity, coke, and Portland cement, is nearly gone. A dependable reserve capacity for electricity, for example, is normally at least 15 per cent of peak load; but by the end of 1947 the reserve capacity had dwindled to less than 1 per cent for the whole country, and in some parts of the country there were acute shortages. Under such circumstances an unexpected natural development may cause near-disaster, like the water shortage and resulting electricity "brownout" in California in the winter of 1947-1948. With the greatest industrial nation on earth so pressed by inadequacies in its industrial plants, we can readily undestand the craving for industrial development among the less industrialized countries.

Factors favoring localization of manufacturing. Modern manufacturing must have raw materials, sources of mechanical power, a labor supply, and machinery. It must also have a market in which the final product can be consumed. The choice of localities for the establishment of manufacturing centers is less restricted than the choice of locations for obtaining the raw materials. Coal is where you find it, and cotton is produced only in areas with climates favorable to its growth and harvest, but modern transportation and mobility of power permit factories to settle at a wide choice of localities. The determining factor is likely to depend upon a balance between the costs of hauling the raw materials and supplies of power on the one hand and the cost of hauling the manufactured products to market on the other.

In actuality, the modern industrial regions of the world have grown up (1) where coal and, more recently, hydroelectric power or petroleum have been available; (2) where raw materials are produced; (3) in or near large centers of population where there is an abundant labor supply and a good market of consumers; and (4) at good trading locations, to which both materials and labor can be brought at reasonable expense, and from which the finished products can readily be shipped to wider markets. Obviously these factors are interrelated, and in a given manufacturing district two or more of them are commonly important. The factor of capital plays a minor role in the location of industry, as capital normally flows easily to points where maximum profits with safety are anticipated.

Courtesy U. S. Steel Corp.

(A.) Bessemer converters in action at Carnegie-Illinois Steel Corporation plant, Gary, Indiana. The converter at right is receiving its charge of molten iron brought from the blast furnace, while that at left is belching flame in the middle of the "glow" that oxidizes the carbon and other impurities.

The geographical distribution of population, agricultural and forest raw materials, and power and mineral resources have been described successively in the preceding portions of this book. It remains to be shown how these human and natural resources have been brought to focus in certain areas to develop manufacturing. In no phase of geography is the interdependence of all regions—rural, mineral, urban—more clearly visible than in manufacturing.

1. Industrial concentration near coal fields. Early in the Industrial Revolution a large and cheap supply of power became necessary for any important industrial development. Such a supply was found in coal fields. Coal can be used both for direct treatment of raw materials, as in iron smelting (see page 429), and to generate steam power from water to turn machinery, as in the textile industry. As coal is a bulky material of relatively low value, it cannot be transported over long distances without incurring heavy freight charges and thus becoming too expensive for large-scale manufacturing industries. Heavy industries therefore early began to congregate in or near the coal fields. (See map, p. 427.)

Courtesy U. S. Steel Corp

(B.) Open hearth furnace being charged with molten iron from huge ladle transported by overhead crane from the blast furnace. A portable trough conducts the iron from the ladle through the furnace door. In the open hearth method of steel manufacture, air passes over the surface of the metal rather than through it.

2. Principal industries associated with coal fields. From the beginning of modern industrialization, certain types of manu-

facturing industries have grown up close to coal mines. Among these, the iron and steel industry ranks first.

The Machine Age is utterly dependent upon the use of large quantities of iron and steel, both for the machinery of manufacture and the modern means of transportation. The use of charcoal in blast furnaces was abandoned relatively early, but the larger the furnaces and steel mills grew, the more they became dependent upon a cheap supply of coal as a source of both fuel and power. Originally, nearly two tons of coal were needed in the form of coke to recover the iron (as pig iron) from one ton of ore. Consequently, where iron ore was not available in close proximity to the coal fields, it was cheaper to ship the ore to the coal than to ship the coal to the ore.

At present, as a result of technical progress, one ton of coke can smelt two tons of iron ore. However, pig iron is only a semifinished product and must be made into cast iron, wrought iron, or steel, through further processes of manufacture, all of which require substantial amounts of additional fuel and power. In modern plants, to conserve fuel and time, the molten iron from the blast furnaces is not allowed to cool and harden into *pigs*, but is poured directly into the open hearth furnace, Bessemer converter, or other furnace for purifying and alloying (see Illus. A and B, p. 484). Notwithstanding such economies, in the United States, on the average one and a half times as much coal as iron ore is needed for the manufacture of steel. Thus, although the iron and steel industry is not bound to coal as closely as it was in the past, it still is found primarily in association with coal fields. Furthermore, steel can be of use only when made into various industrial goods, and for the manufacture of each of these, from rails and structural steel to the most intricate and heavy modern machinery, a large supply of cheap power is essential.

There are many other industries for which cheap fuel and power are essential and which therefore tend to congregate in or near important coal fields. Examples are: the glass industry; the pottery industry; those chemical industries which use coal tar—the tar residue which remains after the manufacture of coke—as a basic raw material; and the textile industries, especially the manufacture of cotton and woolen goods. Many of the coal fields of the industrial countries, then, have become centers of diversified industry.

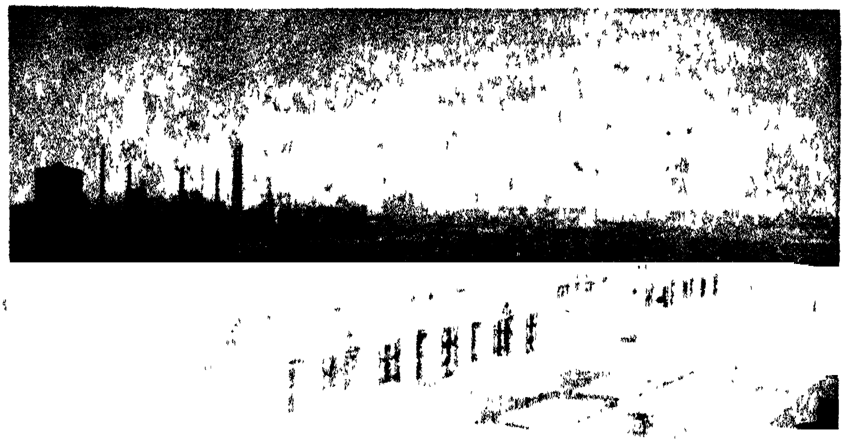
Courtesy Standard Oil Co. of New Jersey.

The path of a pipeline through the woods near Fluker, Louisiana. Once buried, the pipeline leaves little mark on the landscape except its cleared right-of-way and its occasional valves or stations. Here a linewalker is clearing weeds from around a valve.

Secondary coal-using industries tend to

develop along the routes over which raw materials are transported to coal fields. Thus, iron-ore ships and trains carrying return cargoes of coal from the Pittsburgh area have favored the development of secondary industries along the Great Lakes. Duluth-Superior, the chief iron-ore shipper, is also the chief receiver of water-borne coal among Great Lakes ports (see Illus. p. 423).

3. **Effects of other forms of power upon industrial concentration.** The more recent and more easily distributable forms of power available to industry have until lately done relatively little to counteract the tendency of manufacturing industries to congregate in concentrated areas. Although originating mostly outside the established industrial districts, petroleum, fuel oil, gasoline, and natural gas have tended to flow to existing centers of manufacture by means of cheap pipe-line, tanker, or rail transportation rather than to attract industrial areas themselves (see Illus. p. 382). Similarly, electric power, derived from falling water, coal, natural gas, or fuel oil, can be distributed over ever-increasing distances. The availability of cheap electricity far from its place of origin is helping to counteract an unwieldy degree of industrial concentration, but it cannot be expected to cause a complete decentralization of manufacturing. Areas where power is available at low cost and where agglomerations of population constitute great markets will continue to be the most logical sites for certain types of industry.

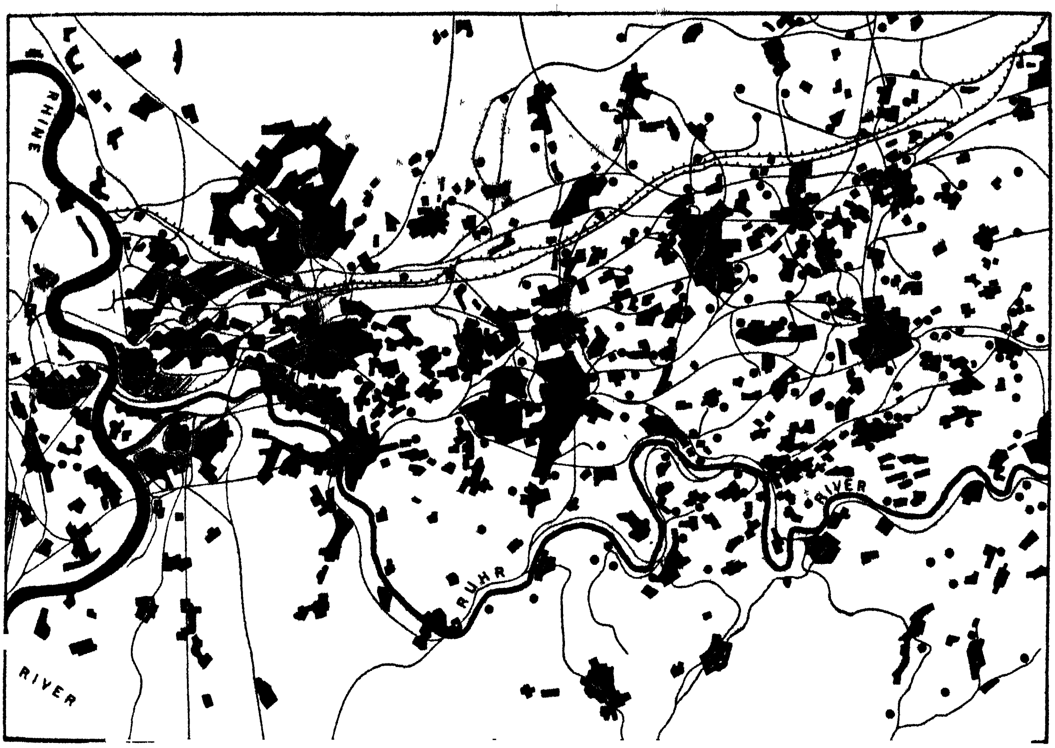


Industrial urban landscape in the Ruhr district, Germany All too often factories are surrounded by monotonous rows of crowded dwellings

4. **Industrial development near raw materials.** Many specialized manufacturing industries have grown up near the sources of raw materials. In the food processing industries, for example, the raw materials are so perishable and so much superior when processed fresh that the canneries and other processing plants are built within easy hauling distance of the farms or fisheries. Industries such as copper smelting or lumbering, which involve the handling of large weights of waste material in proportion to the processed product, also find it advantageous to save transportation bills by locating near the source. To save unnecessary crosshauling of the finished product, many consumer industries tend to develop in widely scattered areas. Petroleum refining, for example, an industry that

produces its own fuel, is extensively developed not only near Texas, Louisiana, and California oil fields but also near the big population centers of eastern United States. Areas producing petroleum and the nonferrous ores have not led to the development of large diversified industrial districts as have the coal-producing areas.

5. INDUSTRIAL DEVELOPMENT NEAR TRADE CENTERS. The two largest cities of the world do not have local resources either of fuel or raw materials, yet London and New York have become the centers of major manufacturing districts. The great original and continuing advantage of this type of industrial area is a location favorable to good transportation and trade. By being able to tap the raw materials and fuel from the heart of the United States and from the countries bordering the Atlantic, New York early attracted traders, and as the population grew it provided a labor pool for manufacturing industries and a large local market for the manufactured products. Such commercial centers favor the development of consumer-goods industries requiring large amounts of labor and skill, such as the clothing industries of New York and Paris, the electrical goods industry of London, and the printing and confectionery industries of Boston.



Ruhr district, a thickly settled industrial region. Built-up areas shown in black, coal mines by dots. Note dense net of railroads, rivers and canals.

All densely settled areas, including ones that developed on the basis of coal fields and heavy industry, encourage the rise of consumer-goods industries by the very fact of the needs of the population for food, clothing, and other goods.

Effect of industrialization upon the cultural landscape. Industrialization has far-reaching effects upon the distribution of the population and upon the appearance of the cultural landscape. It fosters the growth of industrial nuclei, leaving areas of sparse population between. In New England, for example, extremely dense population in the industrial cities and valleys occurs next to thinly settled areas on adjacent upland. Agriculture may suffer from the loss of labor, owing to the greater remuneration offered by work in the near-by industrial centers. Dairying and truck farming to feed the cities, however, develops in an extensive surrounding zone.

In some of the more extreme cases an entire region may become urbanized Mine hoists, culm piles, factory buildings innumerable smokestacks, row upon row of dreary tenement houses or workers' cottages, and vast railroad yards with miles of track all but obliterate the natural landscape (see Illus. p. 486). Such conditions are found in the Ruhr Basin of Germany, the so-called Black Country near Birmingham, England, and other areas.

The transportation network is strikingly affected by industrialization. The growth of manufacturing is accompanied by improvement of the means of transportation, so essential to modern industrial development. Raw materials must be transported into and within the area, semimanufactured products must be moved and finished goods must be distributed. Nowhere else in the world is the railroad web so dense and so intricately woven as in some of the large industrial districts. In the lower Rhine region of Germany, for example, there are over 25 miles of railroad per 100 square miles, while in highly industrialized and densely populated Belgium this figure rises to over 55 miles. In the Ruhr district, adjoining the Rhine, there are over 3,000 miles of railroad track (see Illus. p. 487). Where water transportation is available, as in northern France, Belgium, and the Netherlands, it is often used for short hauls as well as for relatively long ones. Rivers are deepened and regulated and canals are built. The principal British industrial districts all have easy access to the tidal waters, while those of the United States are within easy reach of the Atlantic, the Pacific, or the Great Lakes waterway. In recent decades, the network of roads has been greatly improved in most of the important industrial districts as a response to the rapid increase in the use of trucks as freight carriers and as links between rail or water and factory.

The principal industrial districts of the world. The upshot of the interplay of the factors just discussed has been the development of the world's great industrial areas. The main diversified heavy industry areas are in the northeastern quarter of the United States and in northwestern Europe (see Illus. p. 482).

Industrial districts of northeastern United States. In the United States, a highly industrialized and densely populated region stretches inland as a relatively narrow discontinuous belt from the Atlantic coast between Boston and Baltimore to a line drawn from Cincinnati through Indianapolis and Chicago to Milwaukee, and including southern Ontario. The states in this region have about one-half the population and a little more than half the income of the United States, but they have over two-thirds of all manufacturing employment, four-fifths of the iron and steel manufacturing, nine-tenths of the automobile manufacturing, four-fifths of the apparel manufacturing, and two-thirds of the chemical industry. Within this section of North America several individual industrial districts can be recognized.

1. THE PITTSBURGH-WHEELING-CLEVELAND DISTRICT. The Pittsburgh-Wheeling-Cleveland district is closely associated with the northern Appalachian coal fields. The presence of high quality coking coal has fostered the development of an extensive iron and steel industry which is able to import iron ores cheaply via the Great Lakes waterway. While the manufacture of iron and steel dominates, especially in the Pittsburgh and Youngstown centers, numerous associated steel-fabricating industries have developed. The Pittsburgh center has an important glass industry. Akron is the largest rubber manufacturing center of the world, and its district employs about half

the rubber workers of the United States. East Liverpool is noted for its manufacture of pottery.

2. THE NEW YORK-PHILADELPHIA-BALTIMORE DISTRICT. The New York-Philadelphia-Baltimore district, the most densely populated part of the United States, includes, besides the metropolitan areas of the cities mentioned, most of northern New Jersey and a considerable portion of eastern Pennsylvania. The entire district is within easy reach of the northern Appalachian coal fields; it has port facilities that permit importation of raw materials and export of the finished products not absorbed within the district itself; and it has a large internal market. Industry is highly diversified, and both the total value of the products and the number of people employed exceed those of any other industrial district. About two-thirds of the national employment in the clothing industry is in this district.

In the Baltimore center, the manufacture of clothing and tinware and the refining of petroleum and copper are among the principal industries. The Philadelphia center manufactures textiles and clothing, iron and steel, foundry products, and electrical apparatus; it refines petroleum and sugar and makes cigars, leather goods, and a host of other products. Iron, steel, foundry products, locomotives, silk, rayon, and knit goods are important manufactures in other centers of eastern Pennsylvania. Among the principal industries of the New Jersey center are the silk and rayon industries of Paterson, the manufacture of electrical apparatus and pottery, and the refining of petroleum and copper. Diversification of industry is greatest in New York City; among the innumerable industries, clothing and fur manufactures stand out as employing exceptionally large numbers of workers. Other important manufactures are foundry products, electrical apparatus, chemicals, perfumes, knit goods and other textiles, and printing and publishing products.

3. THE SOUTHERN NEW ENGLAND DISTRICT. The early development of the textile industries of southern New England was due mainly to the availability of cheap water power. Coal was later imported from the near-by Appalachian region either by rail or by means of coastal navigation. At present, as in most industrial districts in the United States, the energy used in the factories is mainly in the form of electrical current derived either from coal or water power. The textile and shoe industries still dominate the economic life of the region, but the former is meeting stiff competition from the southern Piedmont region. The shoe industry also has suffered from the competition of factories located closer to sources of raw materials, in this case western. New England industry is now highly diversified. Among the best-known specialties are the brass, electroplating, and firearms industries in Connecticut, the jewelry industry of Rhode Island, the manufacture of paper in the Connecticut valley of western Massachusetts and in southern New Hampshire, and the manufacture of carpets, wire, abrasives, and textile machinery in the Worcester center.

4. THE DETROIT DISTRICT. The Detroit district, which includes also the cities of Lansing, Flint, Pontiac, and Jackson, specializes in the manufacture of motor vehicles. Directly or indirectly associated with this industry are important iron and steel, foundry, machine tool, wire, and paint industries. The Detroit River, a strategic link on the Great Lakes waterways, is one of the busiest stretches of water in the world. Its flow of raw materials can be tapped by the Detroit automobile manufactures. Immediately to the west lies one of the important furniture manufacturing centers of the United States, that of Grand Rapids, based in part upon an original source of hardwood and in part upon the household needs of the new midwestern population.

5. THE SOUTHERN LAKE MICHIGAN DISTRICT. The southern Lake Michigan district includes the Chicago area and parts of the neighboring states of Wisconsin and Indiana, with the cities of Milwaukee, Gary, and South Bend. Because of its large market area and its easy access to both the iron

ore of the upper Great Lakes district and the coking coal of the northern Appalachian field, this district is able to support a flourishing iron and steel industry. Closely associated with this industry are an important foundry industry and the manufacture of railroad equipment, farm machinery, electrical machinery, power engines, wire, motor vehicles, and various other goods. Because of an extensive agricultural hinterland with which it has excellent communications, Chicago has become the foremost meat-packing center in the United States, the value of the animal products ranking a close second to that of the manufactures of metal. Other industries of this district include the manufacture of clothing, furniture, paint, and printing and publishing products.

6. OTHER DISTRICTS. Among other important manufacturing areas within the northeastern industrialized belt are the Mohawk Valley district of diversified manufactures from Buffalo and Niagara Falls to Troy; the Cincinnati-Dayton-Columbus district of southwestern Ohio; and the Indianapolis center.

Industry in the South and West. World War I and World War II were both accompanied by large increases in the manufacturing industries of the United States. In the course of the latter war, construction of new plants totaled about 10 billion dollars, and postwar construction has added about 5 billion dollars to this figure. Though all parts of the country have shared in this increase, the rate of growth of manufacturing has been far greater in the South and West than in the older industrial areas of the Northeast. Since the war, industry still has been growing about three times as fast in the South and West as in the Northeast.

This regional redistribution of industry was under way even before World War II. It was, however, accelerated by the wartime desire to decentralize industry for greater security against attack, to save transportation space by producing consumer goods locally, to utilize local resources more fully, and to promote a better balanced economy for the country as a whole. Government prewar action in providing vast new sources of hydroelectric power on the Tennessee, Colorado, Sacramento, and Columbia rivers has stimulated development in the South and West. In the postwar period, the continuation of hydroelectric development and the reduction of freight differentials between the East and the other parts of the country should encourage the present trends. Population growth, especially in the far west, provides a growing labor supply and consumer market. Finally, development and expansion of any industry in a region results in higher income for that region, followed by additional migration of people to the area, which in turn provides the bases for new and expanded consumer-goods industries. The expansion cycle, once under way, is self-feeding for a considerable period of time, and the industrial trend toward the South and West at present shows no signs of overall slackening, though some special war industries, such as military aircraft building, may expect peacetime declines.

1. THE SOUTH. Industrial development in southeastern United States, from Virginia to Texas, has made consistent but uneven progress since the 1920's. The leading manufactures are those devoted to processing raw materials produced within the region. In textiles and lumber, the South leads the United States, with annual production between 40 and 50 per cent of the national total. In both of these industries the rate of increase continues high. The cotton textile industry, using near-by sources of raw cotton, centers on the Piedmont and the southern Appalachian area. More recently, the rayon industry has become well established in the northern part of this region (see Illus. p. 491). The lumber industry finds its raw materials throughout the South, with emphasis now upon Longleaf Yellow Pine from the Outer Coastal Plain, cypress from swampy spots in the Plain, and hardwoods from the Piedmont and Appalachian plateaus.

Food and tobacco processing are major

and growing industries in the South. The manufacture of iron and steel has long been an important industry in Birmingham, Alabama, where the juxtaposition of suitable coal, iron ore, and limestone flux creates one of the country's best natural sites for the iron industry. Compared with the industrial northeast, Birmingham has a freight advantage for supplying most of the southeastern and southwestern United States. Petroleum and coal industries, based primarily upon the Texas-Louisiana-Oklahoma fields and the Appalachian mines, account for one-third of the United States' manufacture of those products. Airplane manufacture in Texas and shipbuilding in Charleston, Mobile, and other ports are examples of industries established as part of the wartime expansion and decentralization program.

In most of the lesser industries, the South is increasing proportionately faster than the Northeast. Some of these growing industries are related to local raw materials, as, for example, the sulphur industry of Texas and paper, chemicals, and synthetic rubber manufacturing. Others, such as furniture, leather goods, and printing, are stimulated not only by the presence of raw or semifinished materials but also by the existence

Fairchild Photo, Courtesy American Viscose Corp.

Viscose rayon plant at Roanoke, Virginia, one of the oldest rayon centers of the United States One of several consumer industries that have sprung up in the Piedmont region of the South, taking advantage of nearby raw material and fuel as well as plentiful labor, land, and water.

of the consumer market heretofore depending upon "imports" from the Northeast. The cheap power made available by the Tennessee Valley Authority has favored the establishment of aluminum and other industries.

2. THE MIDDLE WEST. The midwestern farm states of the Minnesota-Montana-Colorado-Missouri quadrangle, after lagging behind the rest of the country in industrial development, have shown decided gains in regional percentage of output in most fields of industry since 1940. Food processing remains by far the major industry of this region, based primarily upon the abundant production of wheat and beef. Along the eastern side of the region the great food-processing centers of Minneapolis-St. Paul, Omaha, Kansas City, and St. Louis have branched out more and more into other industries as well, and smaller cities also have developed industrially in recent years. Several aircraft plants were built in this area during World War II. St. Louis, the largest of these cities, has the advantage of near-by sources of coal and an exceptionally central position for rail, water, and air transport. It has developed important apparel, leather, shoe, and machinery industries. More and more the Midwest may be expected to provide its population with their consumer-goods needs.

3. FAR WEST. The most striking population gains in the nation in the ten years after 1940 were made in the Far West. The increase in population of the three Pacific Coast states was about 50 per cent during that period; in Arizona and Nevada, it was more than 30 per cent. The increased population provided an increased labor supply and consumer market and helped to stimulate the already greater-than-average rate of increase of manufacturing. In all major census categories of industries except lumber, employment in 1947 was greater than in 1939.

The two biggest industries in terms of number of people employed—food and lumber—illustrate the same dependence upon local raw materials as is shown by industries in the South. The food comes chiefly from the California lowlands and the eastern Washington grain area; the lumber, from the mountains of Oregon and Washington. Next in importance is the manufacture of transportation equipment, chiefly airplanes, which have proliferated before and during the war in the Los Angeles and San Diego areas of southern California and elsewhere, partly as a result of the favorable climate. Petroleum refining in southern California, wartime-established shipbuilding in Portland, and chemical and aluminum industries of the Seattle area and hinterland aided by the Bonneville and Grand Coulee power developments are among important new or expanded industries. In textiles, apparel, printing, and other consumer-goods industries, as well as in iron, steel, and machinery production, the West is attempting more and more to meet its own requirements instead of depending upon products freighted in from eastern United States.

Europe. In Europe, industrial development is greatest in a belt that stretches from the British Isles through northern France, Belgium, Germany, Poland, and Czechoslovakia into southern Russia. The major industrial districts, with the exception of that of London, all lie on or near important coal fields. (See map, p. 482.)

1. GREAT BRITAIN. The Scottish Lowland district centers around Glasgow, where metal industries include a wide variety of manufactures ranging from railway locomotives to fine precision instruments. Shipbuilding flourishes along the banks of the Clyde River, where some of the largest ocean-going vessels ever built have been launched.

The Newcastle district also has a highly developed shipbuilding industry and manufactures marine engines and railroad equipment. As in the Clyde district, the specialization in heavy products is favored by the juxtaposition of coal fields and tidewater. The Pennine Chain of central England is ringed with coal fields. On the east side of the Pennines, woolen goods are a specialty around Leeds, while farther south Sheffield is renowned for its metal products, especially cutlery. (See map, p. 369.)

The Lancashire district, west of the Pennines, long has been the foremost cotton textile manufacturing region of the world. The industry centers in the numerous cities which surround Manchester, especially to the north. Besides textiles, chemicals and glass also are produced in large quantities. A short distance to the south lies the famous Potteries district where all sorts of pottery are made, varying from tile and crude earthenware to the highest qualities of chinaware. The principal city in this district is Stoke-on-Trent.

In the Midlands district, south of the Pennines, Birmingham has a highly diversified industry that produces automobiles, rubber, rayon, electrical equipment, arms, and many other products, while Nottingham specializes in the manufacture of hosiery and laces. In South Wales, the Cardiff area has an iron, steel, and shipbuilding industry.

London, like New York, has a large number of highly diversified industries which profit from excellent transportation facilities, a good supply of labor, and the presence of an immense market.

2. CONTINENTAL DISTRICTS. On the European continent the Ruhr and Lower Rhine districts of Germany stand out as highly industrialized areas. Within a territory of less than 50 miles from east to west and 25 miles from north to south lie more than a dozen cities with populations varying from 100,000 to over 500,000, besides a host of smaller ones. The coal, iron, and steel of the Ruhr normally lead Europe in production in peacetime, and in wartime they provided the equipment with which the Nazis overran most of the continent. Little wonder that the problem of how to use the Ruhr to promote European prosperity while preventing its use for a third time as an arsenal against democracy is one of the knottiest and most-discussed questions of Europe. This district manufactures all kinds of metal products, from the heaviest machinery to knives and needles. Textile and chemical manufactures also are important.

Other important industrial districts closely associated with coal fields are in northern France, Belgium, and the Silesian area, on the Poland-Czechoslovakia border. The Saxony and Bohemia districts were developed originally on the basis of available metal and wool resources. Cheap electrical power now is available through the use of the large lignite deposits. Textile, machine, paper, porcelain, and glass industries are highly developed here. The continuation of the coal fields into the Donets Basin of the Ukraine, and the presence near by of the Krivoi Rog iron-ore deposits, have been the basis for the principal iron and steel industry of the Soviet Union, an industry still of major importance, notwithstanding the later development of Ural-Kuznetsk iron and steel industries.

Among the other important industrial districts of western Europe should be mentioned those of the Swiss Plateau and of northern Italy, both of which depend mainly upon hydroelectric power and good transportation connections.

3. OTHER IMPORTANT INDUSTRIAL DISTRICTS OF THE WORLD. In recent decades some important industrial districts have developed elsewhere, as for example the Moscow district of the Soviet Union, the new Magnitogorsk-Sverdlovsk area of the Urals, the Kuznetsk area at the foot of the Sayan Mountains, the Kobe-Osaka and Tokyo-Yokohama centers of Japan, the Mukden area of Manchuria, the Shanghai center of China, and the Bombay center of India. Great progress is being made in eastern Brazil, and in other South American areas. Northwestern Europe and eastern North America, however, remain the dominant manufacturing areas of the world.

Effects of World War II upon industrial development. The destruction of large portions of the industrial plant of Europe through bombing, shelling, and dynamiting in the course of World War II set back seriously the industrial achievements which had been gradually made through generations of patient capital accumulation. The effects of the war were varied in kind as well as in degree; those countries in the midst of the fighting suffered more than those at the margins, and the neutral countries were able in many instances to show increases in production. As an illustration, the production of pig iron in the last prewar year, the last year of the war, and the first postwar year for some of the countries included in the European Recovery Program was as follows (in thousands of metric tons):

	1938	*1945*	*1946*
Austria	551	101	58
Belgium	2,427	700	2,161
France	5,967	1,183	3,437
Italy	884	65	189
Luxembourg	1,551	306	1,378
Sweden	668	789	690
United Kingdom	6,765	7,010	7,846
Germany (Bizonia)	15,700	—	2,215

Source: U. S. Department of State, Committee of European Economic Cooperation, 1947.

In many other fields of basic production, fluctuations were similar. Greece estimated that her losses represented the savings of several decades, if not a whole century. In the Soviet Union it is estimated that about one-third of the industrial capital of the country was destroyed. In China, the meager industry suffered profoundly from Japanese occupation and subsequent civil war. For most countries there were heavy losses of all forms of transport, essential to healthy industrial development. Between 1939 and 1946, for example, the merchant marine declined in gross tonnage in the following approximate percentages: Norway, 40 per cent; Greece, 60; Germany, 80; Japan, 80; and Italy, 85. The British fleet remained about constant. Only one industry showed substantial increase of postwar production in every country of western Europe: electric power. Total electric power production in the countries of the European Recovery Program was more than 50 per cent higher in 1947 than in 1938.

In some countries far from the scene of military operations, such as the United States and Canada, production capacities increased greatly in some fields during the war. Other countries, such as most of those in Latin America, found their industrial development slowed up. Postwar political and military policies of international trade and taxation have been directed in the United States toward rebuilding and improving the productive capacities of western and southern Europe. Shipments also have increased greatly to Latin America, India, and other countries. Many years of constructive effort will be required before a "normal" production economy can be established throughout the world.

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Chapter Twenty-eight

THE ECONOMIC GEOGRAPHY OF SELECTED INDUSTRIES

THE INDUSTRIAL DISTRICTS THAT WE have just considered are made up of a number of individual manufacturing industries. Some of these industries have been discussed in the chapters dealing with the raw materials upon which they are based, such as certain mineral products, coal, petroleum, iron and steel, lumber, fruits, cereals, and tobacco. The following groups of manufacturing industries not yet considered will be treated individually in the pages to follow: chemicals, textiles, wearing apparel, rubber products, leather goods, machinery, electrotechnical products, and transportation equipment.

No attempt will be made to describe in detail the processes of manufacture: that is the province of industrial geography rather than of general economic geography. Attention will be paid here rather to the facts and causes of localization of the industries.

Relative importance of the major groups of manufactures. It would be geographically interesting to rank the manufacturing industries of the world in the order of their importance. Unfortunately there is no international system of classification of manufactures, and therefore it is difficult, and in many instances impossible, to make comparisons between countries. The United States Bureau of the Census has adopted a classification into twenty major groups which serves this country quite well. In order to obtain a fair idea of the relative importance of the groups, various criteria might be chosen, such as value of products, cost or quantity of raw materials used, capital invested, power used, men employed, or value added by manufacture. No single criterion is perfect. The accompanying table gives the value added by manufacture in 1939 and the average number of employees in each industry. As used in the census reports, the term "wage earners" in manufacturing does not include personnel engaged in distribution or construction: in other words, persons not primarily engaged in manufacturing activities in the narrow sense of the term.

As shown in the table, the food industries lead in value added by manufacture, while the textile industries lead in number of people employed. However, if the iron and steel and the machinery manufacturing industries were combined, as might well be done since machinery is very largely made of iron and steel, they would rank first by far on both scores.

It is noteworthy that the chemicals and mineral fuels industries, though ranking relatively low in the number of people employed, show the largest value added by manufacture per employee.

TABLE XIV

MAJOR GROUPS OF MANUFACTURING INDUSTRIES OF THE UNITED STATES (Census of Manufactures, 1939)

Group	*Value Added by Manufacture (in millions of dollars)*	*Wage Earners and Salaried Personnel (in thousands)*
*Food and kindred products	3,583	937
Textile-mill products and other fiber manufactures	1,809	1,138
Apparel and other finished products made from fabrics and similar materials	1,395	812
*Iron, steel, and their products, except machinery	2,956	1,083
Machinery, except electrical	1,969	630
Electrical machinery	1,000	314
Automobiles and automobile equipment	1,322	445
Transportation equipment, except automobiles	472	185
*Nonferrous metals and their products	825	263
*Lumber and timber basic products	618	385
*Furniture and finished lumber products	627	326
*Paper and allied products	870	296
Chemicals and allied products	1,880	350
*Printing, publishing, and allied products	1,776	468
Leather and leather products	1,390	352
*Stone, clay, and glass products	911	320
*Products of petroleum and coal	675	124
Rubber products	406	139
*Tobacco manufactures	350	92
Miscellaneous industries	694	276

* Considered in earlier chapters of this book.

The Chemical Industries

The chemical industries represent one of the most important and rapidly developing branches of manufacturing. They are basic to many other industries, for they supply much material for manufacturing, agriculture, and mining. Because of their importance for military activities, chemical industries were fostered in countries where they did not previously exist or were poorly developed, following the needs felt in World War I.

The chemical industries obtain some of their principal raw materials directly or indirectly from minerals, such as sulphur and pyrite, ordinary salt, potash salts and phosphates, sodium nitrate, and coal tar. Other raw materials are of plant or animal origin; still others come from water and even from the air.

Principal products and branches of the chemical industries. The chemical industries manufacture such a host of different products that it is difficult to classify them under a few headings. Some chemicals may be considered as finished products, while a large number of others are only semimanufactures serving as raw materials for other branches of industry.

The chemical industries proper produce many important acids, such as sulphuric acid, hydrochloric acid, nitric acid, acetic acid, and citric acid. The alkalies constitute another group of chemicals. The sodium carbonates, sometimes found in nature but more generally manufactured from common salt with the aid of limestone, are especially important. The industry usually is associated with salt deposits, and the alkalies it produces are further utilized in the manufacture of soap. Other important groups of chemicals are the bleaching compounds, used extensively in the textile industries, and the plastics (cellulose, protein, and other compounds). Among the latter should be mentioned rayon, made from the cellulose contained in wood pulp or cotton linters.

Among the principal specialized branches of the chemical and closely allied industries are the manufacture of fertilizers, explosives, dyestuffs, paints, drugs and medicines, and soap.

SULPHURIC ACID. Sulphur and pyrites serve largely as the basic raw materials for the manufacture of sulphuric acid, a substance which is indispensable in so many processes of industrial chemistry that the amount of its output is sometimes used as a barometer of industrial activity. The manufacture of sulphuric acid in this country began in 1793, and by 1947 annual production surpassed 10 million tons. The United States and Italy possess the largest stores of crude sulphur; Spain, Japan, Norway, Italy, and Cyprus are the principal producers of pyrite. The United States, highly industrialized and with well-developed chemical industries, ranks first in the production of sulphuric acid; Italy, less developed industrially, ranks in only third place among the European producers. The markets for pyrites are chiefly in the countries of western Europe, especially Germany, the United Kingdom, and France.

As new chemical inventions have been made, attention has shifted away from the sulphuric acid industry; but the manufacture of some of the new products, such as viscose rayon, requires the use of sulphuric acid, and the United States annual production of this acid more than doubled between 1939 and 1947.

Drugs and medicines. Drugs and medicines, especially those manufactured by synthetic methods, are made primarily in countries with a highly developed chemical industry. As a result, their manufacture shows a distribution somewhat similar to that of the chemical industries as a whole.

Soap. Soap is made from animal or vegetable fats with the aid of alkalies, such as soda or potash. The principal fats used are tallow, coconut oil, cottonseed oil, palm oil, peanut oil, and olive oil.

In the United States the industry is found in nearly all states, but the more important centers are in the East and in Ohio, Illinois, and Indiana. France is noted for its production of fine toilet soaps.

Dyestuffs. Dyestuffs hold high rank among the various chemical industries. In most parts of the world the old, natural dyes obtained from the vegetable and animal kingdoms have been supplanted by the much cheaper synthetic products. The principal raw material is coal tar, a by-product of the coke industry, which can easily be obtained wherever coking coal is available. Because of the intricate processes involved, the industry has developed only in the more advanced industrial countries of the world.

Coal-tar dyes were made first in Germany, which until World War II was the world's largest producer. As a result of that war, the United States replaced Germany in the world market and is now by far the leading producer. Other important producers are England, the Soviet Union, Japan, France, Italy, and Switzerland. The United States and Switzerland are now the only countries which consistently export dyestuffs in excess of their imports.

Paints and varnishes. Raw materials for the manufacture of paints and varnishes are furnished by other branches of the chemical industry and by closely allied industries. The industry is quite widely scattered and plays a relatively unimportant role in international trade; it is generally cheaper to ship the pigments than the finished products. In the United States, the principal centers of production are in the industrial East (New Jersey, New York, Ohio, Pennsylvania) and in Illinois and Michigan. Michigan developed paint manufacturing in response to the needs of the automobile industry.

Explosives. The explosives industry is closely associated with the manufacture of nitrogen fertilizers. Its products, especially dynamite, are used extensively in quarrying and mining and for war purposes. The industry is rather highly decentralized because of the danger involved in the manufacture of some of its products and in the transportation of many of its finished products; the plants are therefore located mostly in country districts rather than in cities.

Fertilizers. The manufacture of superphosphates and potash fertilizers depends primarily upon raw materials—raw phosphates and potash salts—furnished by the mineral industries (see Chapter Nineteen). European potash comes chiefly from Germany and France (see Illus. p. 330). The manufacture of superphosphates is related less to the deposits of raw phosphate, in northern Africa and Florida, than to the centers of consumption (see Illus. p. 319). The industry, therefore, is quite widely scattered. In the approximate order of their importance, the principal prewar manufacturers of superphosphates were the United States, Japan, France, Italy, Australia, Spain, Germany, and the Netherlands. The total production of Europe normally is more than twice that of North America.

Nitrogen fertilizers are produced in different parts of the world and in various ways. The soda nitrate mined in Chile, although it has lost its monopoly, still occupies a position on the world market, providing in normal years 7 to 8 per cent of the world's supply (see Illus. p. 322). At present, the principal nitrogen fertilizers are provided by the chemical industry, chiefly from ammonium sulphate, some of which is produced synthetically and some as a chemical by-product of the coke industry. The location of the industry is generally determined by the availability of cheap hydroelectric power. Europe accounts for about half of the world production of this fertilizer, Germany normally occupying first place. Other large producers are Japan, the United States, Great Britain, Korea, and France.

PLASTICS AND FIBER SYNTHETICS. When two British chemists found in 1856 that they could make a substance resembling ivory by soaking rags or paper in acid and mixing with camphor into a doughy mass, they were laying the foundations for an industry that would some day be able to replace wood, glass, cotton, wool, and silk for a wide variety of purposes. In 1869, important changes in the process were introduced by Hyatt of New Jersey, and the resulting material, known as celluloid, became the first American plastic. Though this ivory-like material soon became popular for such things as piano keys, combs, and knife handles, inflammability was long a disadvantage. Not until the rise of radio in the 1920's created a demand for molded cases did plastics begin to come into their own as a competitor with cabinet woods.

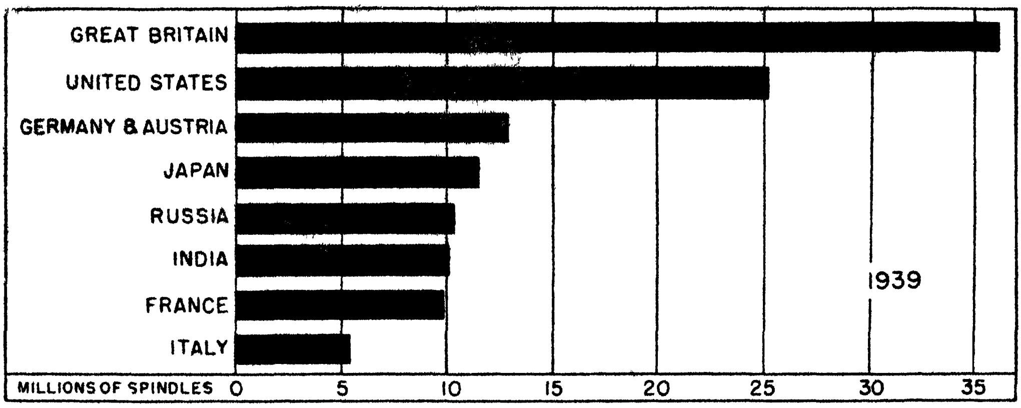
The plastics most used today are made principally of cellulose or of protein. Cellulose, the inert framework substance of plants, is obtained for industrial purposes chiefly from wood or cotton. Cellulose acetate is made by treating cotton linters with acetic acid and acetic anhydride. It is the raw material not only for plastics but also for acetate rayon, the earliest of the synthetic textiles. The use of wood pulp as a source of cellulose for synthetic products is the foundation of the viscose rayon industry (see Illus. p. 491). The wood pulp is treated with caustic soda and bisulphide of carbon to make the gelatinous mass which is squeezed through a finely perforated nozzle to make the fibers for rayon. The fibers are hardened in a chemical bath.

The protein synthetics use as raw material chiefly soybeans, milk, or dried blood. Various other plastic with special qualities and uses are made from other substances, such as lime and coal (for vinyl) and carbolic acid and formaldehyde (for phenol). A still more recent synthetic product is nylon, the textile fiber made from coal, which became the favorite material for women's hosiery overnight following its first manufacture in 1939, and which now bids fair to rival rayon and cotton for other garments (see also Illus. p. 502). It is difficult to exaggerate the profound and increasing effect of synthetic materials upon the textile, furniture, and building industries.

Textiles and Textile Products

The textile industries fall naturally into three principal groups: (1) textiles, (2) wearing apparel, and (3) cloth articles other than clothing. The first group includes all spinning, weaving, and knitting mills, and through its manufactures provides the raw material for the other two. The raw materials used by the textile industries are chiefly cotton, wool, linen, silk, rayon, and nylon. In the quantity used, cotton far outranks the other materials.

The textile industries include the manufacture of the various kinds of cloth, such as cotton goods, woolens and worsted, linens, silk, rayon, knit goods, and various specialized mixtures. While the manufacture of rayon fiber is a phase of the chemical industries, the making of goods of rayon is a textile industry.



Number of cotton spindles in countries of major cotton production.

The cotton textile industry. Among the textile industries, the manufacture of cotton goods is far in the lead, both in America and in the entire world. The following tabulation shows the value added by manufacture for various classes of textile goods in the United States in 1939:

	Millions of Dollars
Cotton goods (except knit)	573
Knit goods (all)	357
Woolen and worsted goods	274
Silk and rayon goods	172
Woven carpets	93
Lace goods	15
Linen goods	3

Dyeing and finishing added 155 million dollars more to the value of textile goods in 1939.

World distribution of cotton textile manufacturing. The demand for cotton textiles is world-wide. While locally and for specific purposes other materials may be in greater favor, nearly all the people of the earth make use of cotton fabrics in some form. In the warm and in many intermediate climates cotton textiles rank supreme; only in the regions of distinctly cool to cold climate do they yield first place to wool and fur. Since large quantities of cotton still go into homespun cloth, the statistics of commercial mill consumption do not include total world production of cloth. Nevertheless they speak eloquently of the widespread use of cotton goods and of the quantities of raw cotton involved. From 1935 to 1939 inclusive, the world's average annual mill consumption of cotton was 28,541,000 bales.

The relative importance of the various countries in cotton manufacturing is suggested by the number of spindles used in spinning, as shown in the diagram above. The textile mills of Great Britain had about one-quarter of the world's cotton spindles; the United States, about one-fifth; Japan, British India, and China together, another fifth (China, about 4,450,000 spindles); western and central Europe, about one-quarter; and eastern Europe, about 8 per cent. In the southern hemisphere only Brazil, with 2,765,000 spindles, had a sizable textile industry. In cotton consumption the United States had a larger proportion and Britain a smaller proportion than the spindle figures would indicate.

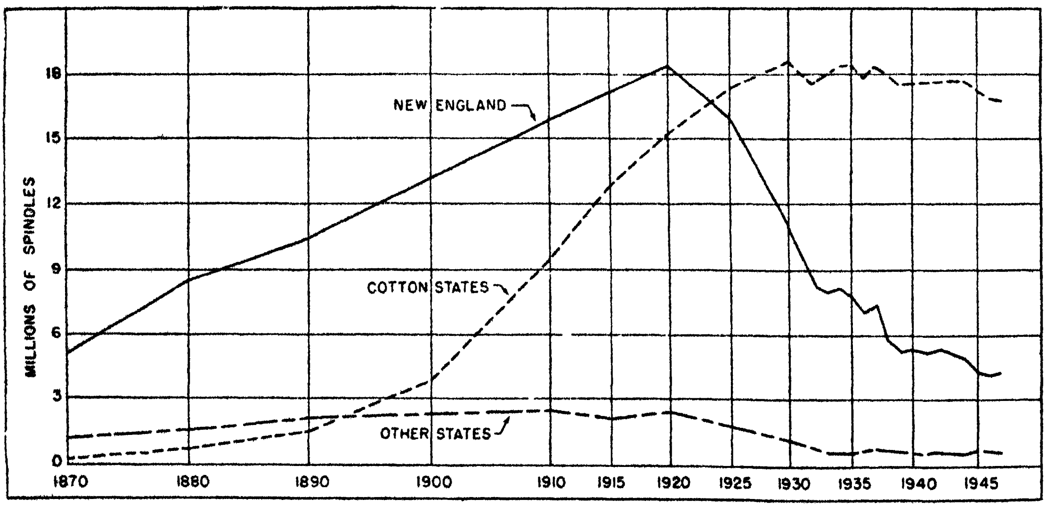
The cotton textile industry of the United States. The outstanding recent development in the cotton-textile industry of the United States has been the shift in geographical distribution of factories from New England to localities nearer the raw material. In the first half of the nineteenth century, when machine methods of manufacture were becoming established in this country, the streams flowing from the glacial lakes and swamps of New England, with their small falls and rapids, provided easily harnessed power resources. The streams had a fairly uniform flow of clear water, and through the building of small dams, numerous additional storage reservoirs could be created. Textile manufacturing became prominent because of cheap and relatively efficient power, raw materials readily obtainable by coastwise traffic, large markets available in the near-by city centers, and the mechanical ingenuity of the New Englanders. Agriculture was finding it difficult to compete with the farm products from the new lands beyond the Alleghenies, and thus a supply of labor became available from adjacent country districts. When steam power came into prominence, it served to supplement the water power, in many instances even to supplant it; but the acquired skill and the large capital investments served to keep New England's supremacy in textile manufactures undisputed until after 1900, as the accompanying table indicates.

TABLE XV

DISTRIBUTION OF ACTIVE SPINDLES IN THE UNITED STATES BY PERCENTAGES OF THE TOTAL

	Cotton States (per cent)	*New England (per cent)*	*Others (per cent)*
1870..	4.6	77.1	18.3
1880.	5.3	81.0	13.7
1890.	10.9	76.1	13.0
1900.	22.4	67.6	10.0
1910	37.2	55.6	7.2
1920..	42.9	51.5	5.6
1930	59.4	36.3	4.2
1940.	74.8	22.4	2.8
1945..	77.6	19.8	2.6
1947..	78.0	19.8	2.2

In comparison with the Cotton States, the relative position of the New England cotton industry has declined during the past fifty years, slowly at first and later at an accelerated pace. The number of active spindles grew steadily until after World War I, though at a much slower rate than in the Cotton States; but since 1920 the number



Active cotton spindles in the United States since 1870, by regions. Source of Data: *Statistical Abstract of the United States*, 1948.

has actually declined, whereas in the Cotton States it has increased (see Illus. p. 500). In 1940, the southern mills processed about 85 per cent of the total amount of cotton consumed in the United States. The shift from New England was mainly toward the southeastern states, particularly the Piedmont of the Carolinas and Georgia. Lesser development occurred somewhat later in northern Alabama and eastern Tennessee. Some cotton weaving is carried on even as far west as Texas, which in recent years has contributed nearly 1.5 per cent of the value of all woven cotton goods, though it has little cotton spinning.

As might be expected, those phases of textile manufactures requiring the least skill moved first, while those dependent upon quality of output have been slowest to shift. The southern regions are noted for their output of medium-grade yarns and goods, while New England holds tenaciously to its fame as a producer of high-grade goods.

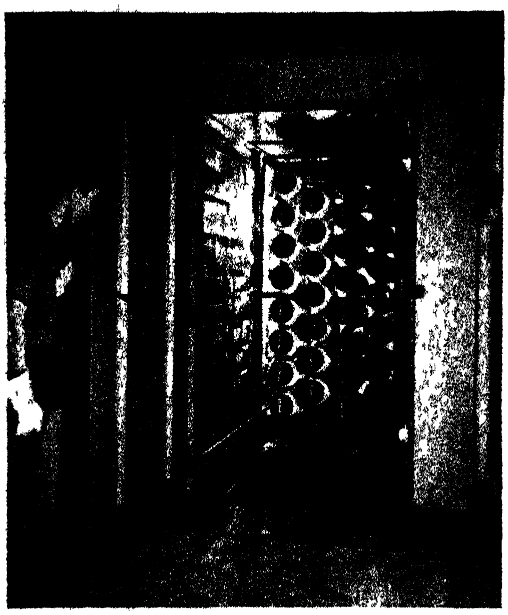
THE COTTON TEXTILE INDUSTRY OF GREAT BRITAIN. The cotton industry of Great Britain is concentrated in the Lancashire district, Manchester being the principal center. Before artificial means had been devised to maintain a desirable degree of humidity in the factories, the damp climate of Lancashire, caused by its location on the west side of the Pennine Chain, was of great advantage for cotton manufacturing. This advantage is still of some economic value. Furthermore, coal for power is available within the district, and the factories are within easy reach of the sea for the importation of raw material and the export of the finished products. Liverpool, at the entrance to the Lancashire area, has long been the greatest cotton-importing and trading center of the world. Before World War II the district suffered greatly from the competition of new textile centers, especially those of Japan, China, British India, and numerous smaller centers elsewhere.

Textiles of silk and synthetic fibers. 1. SILK. Silk, for centuries the aristocrat among fibers, has been supplemented, and now surpassed, by the newest arrivals, rayon and nylon. Japan and China are the greatest silk producers, and their product is used not only in their own domestic industries but also for manufacture of silk textiles in other parts of the world, notably Europe and North America. In the United States the principal centers are in Pennsylvania, New Jersey, New York, and Connecticut. Paterson, New Jersey, once the leading silk-manufacturing center of the United States, now produces more rayon than silk. As a silk-manufacturing center it has been eclipsed by the Allentown-Bethlehem and the Scranton-Wilkes-Barre industrial areas. Raw-silk imports virtually ceased during World War II; since then they have been partially resumed.

2. RAYON. The rise of rayon has been the most spectacular development of the modern textile industry. First developed in France as "artificial silk," it soon established itself in several countries where other textile industries were already operating. Machinery, technically skilled labor, and markets for the finished textiles were waiting in those countries. Germany, Japan, and the United States were the leading producers before World War II, but the war resulted in outstanding predominance by the United States. Of the total world production of 1,800,000,000 pounds in 1946, the United States produced 47 per cent. France, Czechoslovakia, Italy, Belgium, the Netherlands, and the United Kingdom also are important producers. Postwar recovery of the industry has been slow in Germany and Japan.

In the United States the first rayon-manufacturing plant was established in 1911 at Marcus Hook, Pennsylvania, by the Viscose Company, the first big producer in this country. In 1917 a second plant was added, at Roanoke, Virginia (see Illus. p. 491). Soon many other plants were established in the area from Georgia to Massachusetts. Although the plants are widely scattered, more than half the production comes from Pennsylvania, West Virginia, Virginia, Tennessee, and Ohio. The major consideration in location is a supply of soft water. Accessibility to spruce or cotton and availability of low-cost labor are other significant factors (see also Illus. p. 183).

The early rayon product was shiny but weak. Gradually quality was improved, until rayon became a fine, soft, lustrous, durable thread, very popular for a wide variety of woven and knitted goods. From about 1 million pounds in 1912, production rose rapidly to nearly 500 million pounds in 1940 and 854 million pounds in 1946. In 1947 nearly 2 billion linear yards of broad woven rayon fabrics were produced in this country, compared with one-half billion yards of woolen and worsted goods and nearly 10 billion yards of cotton goods. Viscose rayon, made of wood pulp, is the principal type manufactured, and acetate rayon, made of cotton linters, holds second place. Acetate rayon textiles are waterproof and are somewhat more costly than viscose. From these two basic materials, a bewildering selection of fabrics of varied types and qualities are manufactured for clothing, draperies, and upholstery. The use of rayon since World War II has increased in virtually every field except that of hosiery.



Courtesy E. I. du Pont de Nemours & Co

Nylon yarn being baked in "twist setting oven" before being wound on spools and cones for shipment from the du Pont plants at Seaford, Delaware, and Martinsville, Virginia.

3. NYLON. The most recent romance of the textile industry has been the rise of nylon. In 1939 the Du Pont Corporation began the first manufacture of nylon, in Delaware (see Table XVI). This synthetic fiber, using coal as its basic raw material, is stronger and more elastic than any previously known fiber. Overnight it became in strenuous demand for women's hosiery. Whereas silk had virtually displaced cotton for women's hosiery in the 1920's, and had been displaced in turn by improved rayon by 1940, nylon has dominated since 1946. War absorbed the first years of big nylon production, chiefly for parachutes, but at the close of the war in 1945 the industry turned to supplying the huge civilian demand. The following tabulation shows the situation concisely:

TABLE XVI

UNITED STATES PRODUCTION OF WOMEN'S FULL-FASHIONED HOSIERY

(thousands of dozen pairs)

	1942	*1944*	*1947*
Cotton	2,471	210	300
Silk	3,319	7	1,098
Rayon	25,167	36,292	3,919
Nylon	3,583	2	33,494

Source: *Statistical Abstract of the United States, 1948.*

The jump in production from 3½ million dozen pairs of nylon hosiery in 1942 to 33½ million dozen pairs in 1947 resulted from the widespread recognition of the qualities of nylon. It retains its shape better, dries faster after washing, and is more durable than rayon, and it is warmer than silk, rayon, or cotton. Having satisfied the pent-up demand for hosiery, nylon is entering new fields. Underwear, nightclothes, window curtains, boat sails, and high-quality cordage are among the goods now available in this light but strong material. The saturation point for present synthetic fiber textiles and for development of new ones is not yet in sight.

Worsted and woolen goods. The countries of the Southern Hemisphere furnish the larger part of the raw wool of the world, although they account for less than half of the world's sheep population. They raise sheep chiefly for wool rather than for mutton and wool, as is done in the north.

The northern countries are the chief manufacturers of wool goods. In prewar production of woolen yarn and cloth, the United Kingdom was followed by Germany, the United States, France, the Soviet Union, Japan, Czechoslovakia, Belgium, and Italy. As an exporter of wool products the United Kingdom held the lead, a position which she will probably continue to hold for some time. Accessible raw materials from the British dominions, cheap power, skilled labor, established plants, and splendid connections with market centers all are factors conducive to success.

In the United States the woolen- and worsted-goods industries taken together rank among the more important in number of wage earners employed (146,000 in 1939). The outstanding centers of manufacture are in New England, especially in Massachusetts and Rhode Island, and in Pennsylvania, with secondary centers in New Jersey, New York, Georgia, Wisconsin, and the Pacific Northwest.

Knit goods. The knit-goods industry uses the various fibers—cotton, silk, rayon, wool—singly for some products and in complex mixtures for others. As a whole it is one of the most important divisions of the textile industries, both as to kinds and value of products and as to number of employees. According to the Sixteenth Census it employed over 250,000 persons. The largest manufacturing centers are in the northeast, from Pennsylvania to Massachusetts. Southern centers have shown a definite upward trend. Localization appears to be chiefly a result of purely economic rather than geographic factors.

Wearing-apparel manufactures. The production of ready-to-wear clothing for men, women, and children is one of the most characteristic results of the shift from handicraft to factory methods. This development is pronounced in the United States, where the great majority of the men and a high percentage of the women buy ready-made clothing. In the Old World the tailors and dressmakers are still depended upon to a considerable extent to make clothes to order, while in the humbler homes the housewives often do much of the garment making, particularly for the women and children. In recent decades, however. even in Europe the manufacture of ready-made clothing for men, women, and children has made great strides, the products appealing particularly to those in moderate economic circumstances.

The manufacture of wearing apparel is one of the major industries of the United States. In 1939 over 700,000 persons were engaged in making clothing. Inasmuch as the labor factor is exceptionally important, the clothing industry tends to be associated with great population centers. While manufacture of wearing apparel is found in practically all important cities, and in that sense it is among the most widely distributed urban industries, the main centers are located in the largest cities. The New York-New Jersey industrial area holds first place in both men's and women's clothing but has a much greater lead in the latter than in the former. The Philadelphia-Camden and Chicago industrial areas hold second and third place respectively, while other important centers are Baltimore, Boston, Los Angeles, St. Louis, and Rochester.

Taken as a whole, the textile and textile-products industries are among the most important manufacturing activities of nearly all industrial countries. Since they deal with necessities of life comparable only with the preparation of foodstuffs, their relative importance continues through periods of adversity as well as of prosperity.

The Manufacture of Rubber Products

Rubber is one of the few major commodities for which the capital interests involved in production of the raw material are nationally distinct from those concerned with its manufacture. More than 95 per cent of the crude natural rubber is produced in the Malay States, the Netherlands Indies, and areas near by, mostly under British or Dutch control (see Chapter Eight). The United States buys about one-half to three-fourths of the world supply, most of the remainder going to European countries.

The rubber industry is to some extent related to that of the textiles in that many rubber manufactures have a fabric or cord base. Rubberized cloth for rainproof apparel, and rubber boots and shoes, were among the earliest products, and their manufacture is still an important phase of the industry. During recent decades the great demand for rubber in the United States and Canada has been for automobile tires, while in Europe the bicycle continues to be the leading consumer.

Rubber in the United States. In the United States the output of rubber products has increased tremendously since the automobile became important. In 1939 the total value of tires and "camelback" was about 600 million dollars. Ohio holds a commanding lead in the manufacture of tires and tubes and also ranks well in the manufacture of other rubber articles. Akron, which accounted for nearly half of the tire production of the United States in 1939, is often referred to as the rubber capital of the world. The production of rubber boots, shoes, soles, heels, and so on, was valued at about 80 million dollars. This left about 215 million dollars of the total value of rubber products for a multitude of items, illustrating the tremendous importance of rubber and the numerous uses to which it is put in our modern economy. Among these may be mentioned different types of hose and tubing, different types of rubberized fabrics, industrial belting, washers, valves, gaskets, insulation products, rubber-covered rolls, hard-rubber articles, matting, and many others. Southeastern New England (Massachusetts, Connecticut, Rhode Island) and New Jersey are the leading centers of manufacture of rubberized footgear and wearing apparel. Nearness to the sea—with the consequent demands for sailors' apparel—a fairly moist climate, and trade with Africa early led to the manufacture of various kinds of waterproof clothing.

During World War II the United States was seriously affected when the Japanese cut off the world's rubber supply by capturing southeastern Asia. Rapid development of synthetic rubber from petroleum and alcohol, and the conservation of domestic tires through gasoline rationing, enabled us to equip the fighting vehicles.

The following tabulation shows our prewar, war, and postwar rubber procurement, in long tons:

	1940	1943	1947
Reclaimed rubber.	208,971	303,991	291,395
Synthetic rubber	2,940	231,722	508,702
Natural rubber (imports). . .	818,624	54,920	688,354

Source: *Statistical Abstract of the United States, 1948.*

Synthetic rubber, which can now be produced in competition with natural rubber on the basis of cost, will undoubtedly continue in large production because it imparts superior wearing qualities to a number of products.

Leather and Leather Goods

Leather serves many purposes. The bulk of it is made into footwear, but considerable quantities are used for machinery belting for the transmission of power in factories and for gloves, luggage, and many luxury articles.

The manufacture of leather. The raw material used by the leather-tanning industry consists of salted or dried hides of cattle and horses and the skins of numerous smaller animals, such as sheep, goats, pigs, calves, alligators, and snakes. With the aid of tannin extracted from different barks, woods, or fruits—such as oak and hemlock bark, quebracho wood from South America, or the cup of a particular kind of acorn from Asia Minor—these hides and skins are made into leather. Chemical tanning materials, especially chromium compounds, are used extensively for the manufacture of light types of leather, such as those in demand for gloves or uppers for shoes. It is estimated that well over one-half of all the leather manufactured in the United States is chrome-tanned.

Originally a rather close association existed between the tanning industry and the forests which furnished the tanning bark. More recently the industry has grown where there is good access to raw hides and consumer markets.

The principal types of hides and skins used are those of domestic animals, and since these animals are found all over the world, the tanning industry is widely distributed. Four countries hold outstanding leadership in leather production: the United States, Germany, the United Kingdom, and France. All four import large quantities of raw material from some of the pioneering countries, particularly Argentina, Uruguay, Australia, New Zealand, and the Union of South Africa, or from tropical countries, as for example, India, which has far more cattle than any other country and where the population, mostly poor and barefooted, does not offer a great domestic market.

Leather tanning in the United States. The United States has a large domestic supply of hides and skins furnished by the meat-packing centers in the Middle West and by small producers on farms. The so-called "packer hides" are generally preferred by the tanning industry because of greater uniformity of workmanship, and they constitute the principal domestic supply. Hides and skins also are imported.

The geographic distribution of the tanning industry within the country still reflects to some extent the influence of two principal tanning materials: oak bark and hemlock bark. The oak tree is most common in the Appalachian Mountains, from Pennsylvania southwestward, while the hemlock occurs farther north in a belt which reaches from New England through New York and Pennsylvania to Wisconsin. Thus, North Carolina, Virginia, West Virginia, and Michigan still produce considerable amounts of leather. Pennsylvania ranks first in leather production, partly because of the early availability of oak bark and partly because the center of origin of chrome tanning, Philadelphia, is within that state. At present much leather is also manufactured in or near the states which have an important boot and shoe industry.

Leather-goods industries. The countries which produce the largest quantities of leather are also the principal manufacturers of leather goods. Among the various products of this industry, shoes and boots rank first.

In the United States, the oldest and foremost center of shoe manufacturing is in eastern Massachusetts and the near-by portions of New Hampshire and Maine. During recent decades the New England shoe industry has lost some ground to rival centers developed elsewhere. The New York industrial region ranks second in the manufacture of leather footwear and is especially noted for women's shoes. There are secondary centers in southeastern Pennsylvania and in and near Cincinnati and Columbus, Ohio.

The shoe industry has shown a marked development in the states farther west. Missouri now ranks third in value of output of boots and shoes, the St. Louis industrial area being the chief center. Illinois and Wisconsin also are important shoe-manufacturing states, with large factories at Chicago and Milwaukee. Exports of American shoes are shipped mainly to Cuba, Canada, and Mexico.

The principal glove-manufacturing district in the United States is located in the Mohawk Valley of upstate New York, where the towns of Gloversville and Johnstown manufacture over half of all the gloves made in this country.

Among the foreign countries that have an important shoe industry, England is known for its excellent qualities of men's footwear. The French shoe industry is outstanding because of its quality and luxury production, primarily of women's shoes. French and English gloves are in demand the world over. Prior to World War II, Czechoslovakia had become an important exporter of footwear, mainly of women's shoes.

The Machinery Manufacturing Industries

The conversion of ores to metals, the refining of metals, and the manufacturing of alloys are properly within the province of the metallurgical industries—that is, the iron and steel, copper, aluminum, and other industries. The shaping of these metals into specific parts and their assembling into workable units is the province of the machine industries. These industries have developed in response to available skilled labor and to markets in need of their products.

The extent to which countries produce machinery is a fairly accurate criterion of their degree of industrialization. The countries of Europe and North America are the only ones with highly developed manufactures of machinery. In Asia, Japan attained considerable prominence after 1920 and India has lately made important progress.

For the machine industries as a whole, the leadership of the United States is undisputed. This supremacy must be attributed to the wealth of raw materials of manufacture, plentiful fuel and power resources, abundance of land and other resources open to development, lack of cheap labor, inventive genius of the people, a large domestic market, and a stable government which has made capital feel secure. No single factor or group of related factors can suffice to account for the industrial achievement of today; it is the result of many factors, some environmental, some economic, and some social and political.

As classified by the census of 1939, the manufacture of machinery other than transportation equipment ranked second in value added by manufacture and third in number of wage earners.

Three branches of the machinery industry which are of special importance because of their relationships to the industrial system in general are: (1) the machine tool, (2) the textile machinery, and (3) the agricultural machinery industries.

Machine tool industry. The machine tool industry is of basic importance because it produces the machines, such as power drills, lathes, saws, shears, and forges, that are necessary in the manufacture of all other machines.

On the basis of the number of wage earners employed, the leading centers are located in Ohio, Connecticut, Illinois, and Massachusetts. There is no clear-cut differentiation in the products made, and it seems evident that the chief requirement for location is accessibility to the factory centers where prompt service in providing and maintaining tooling machines is needed.

Textile machinery. The textile machinery industry includes the manufacture of equipment used in the various kinds of textile mills, from jute to silk, and through all the processes, from working raw stock to finishing the finest fabrics. This industry flourishes to a greater or lesser degree in connection with the textile manufacturing districts in the various countries. Those which have large textile industries invariably have important textile machinery manufactures. This is true of the United States, the United Kingdom, France, Germany, and Italy. Countries of lesser importance in textile manufactures buy more of their textile machinery abroad. Because of the frequent changes in technology in the textile industry, plants must frequently buy improved machinery to keep abreast of their rivals in this highly competitive industry.

In the United States, Massachusetts holds first rank, followed by Pennsylvania and Rhode Island. This industry has been successfully maintained in the northeast despite the southward movement of the cotton textile industry. It is noteworthy, however, that textile machinery factories are beginning to develop in the southeast, particularly in the Carolinas, South Carolina being seventh in number of wage earners in 1939. In shoe manufacturing machinery New England has retained its lead even more completely.

Agricultural implements. Every nation uses agricultural implements of some kind in connection with its farming activities. Where labor is cheap, as in India or China, the equipment is simple, most of it being tools such as spades, hoes, rakes, and flails. Where fields are small and labor only moderately plentiful, as in Sweden and France, more complicated machinery, but of relatively small size, is needed. Only in countries where fields are large and labor scarce, as in Canada, the United States, the Soviet Union, Argentina, and Australia, are there demands for large and highly efficient agricultural implements.

In the manufacture of complex and expensive agricultural machinery, it is inevitable that the country with a large home market should have the advantage, particularly if that country has modern industrial facilities. In the United States, the manufacturers of agricultural machinery are favored by the fact that the country has large iron and steel plants from which they can obtain the needed iron and steel rods, bars, and sheets. The large-scale farming which characterizes much of the country provides a substantial market for the sale of large agricultural machinery. Given these factors, it is easy to understand why the United States has become by far the world's leading manufacturer of agricultural implements.

The principal manufacturing centers in this country have developed where their products are most needed and where the essential raw materials, power, and labor are available. Illinois and Indiana are the leaders in production, followed by Ohio and New York.

FOREIGN TRADE IN AGRICULTURAL MACHINERY. From 1920 to 1929 agricultural machinery was one of our leading exports. In 1929 we sold abroad over 140 million dollars' worth of farm machinery, or about half of our output that year. Chief customers were Canada, Argentina, and the Soviet Union. The depression years (1930-1933) wrought havoc with this business; in 1933 we exported only 12 million dollars' worth. In those four years, Canadian purchases of agricultural machinery from us dropped to one-fifth of their previous value, Argentine imports to one-thirtieth, and Russian to one two-hundredth. The interdependence of industry and agriculture at home and abroad was sharply demonstrated. When the Canadian, Argentine, and Russian farmers could not sell their products to advantage, American machinists lost their markets and jobs. In the postwar period, our exports of agricultural machinery have soared: 158 million dollars' worth in 1946, and more than 300 million dollars' worth in 1947, no doubt in response to the pressing needs abroad for machinery to help rebuild the facilities for food production.

The Electrotechnical Industries

World production of electrical energy derived from falling water and from fuel is increasing rapidly, both in the highly industrialized and the less-developed countries.

North America and Europe produce and consume the bulk of the world's electricity, but even in these continents electrical development is uneven. In Switzerland, Norway, and some parts of the United States, for example, the use of electricity in homes and industries is much more common than in Great Britain, Belgium, Germany, or France, even though the latter are all countries with highly developed modern industries. Even in the former countries, however, there is considerable room for further increase in the consumption of electrical energy. In the United States, low-priced current is being increased by the large-scale hydroelectric and steam-generating plants which have been completed or are planned; in his annual report published March, 1949, the Secretary of the Interior urged that hydroelectric power be increased 40 million kilowatts within the next 20 years beyond the 17 million kilowatts then available.

The hydroelectric industry is one of the few that has increased substantially above prewar levels in western and central Europe. In eastern Europe the huge, industrially retarded Soviet Union is vigorously expanding its output of electric power.

Distribution. In response to this growing use of electricity, the electrotechnical industry, which manufactures machinery and equipment ranging in size from the smallest appliances to the largest dynamos, has rapidly come to occupy a strategic position in the modern economic structure. The principal seats of this industry are found in the countries which have large consumption of electrical energy and at the same time possess highly specialized and well-established machinery industries. Other essential factors are, of course, capital resources and an adequate supply of skilled labor.

In quantity and value of products, the electrotechnical industry of the United States ranks first by far and is followed at a considerable distance by Germany, the United Kingdom, and France. Among the smaller producers must be mentioned especially Canada, Sweden, Italy, and the Netherlands. Japan and the Soviet Union made rapid progress in this field before World War II.

Electricity was first used on a large scale in the great city centers, and they have remained the principal markets for electrical goods. The electrotechnical industries have tended to develop near large cities.

The United States. In the United States the principal manufacturing centers are located in the northeastern industrial area. The Chicago and New York-New Jersey industrial areas lead all others in the production of electrical machinery, apparatus, and supplies. Centers of lesser importance are Philadelphia, Pittsburgh, Boston, Schenectady, Cleveland, Toledo, and Youngstown. Elaborately equipped research laboratories—such as have been established at Schenectady, Pittsburgh, and Cleveland—have been highly effective in promoting the development of the electrotechnical industry. Their discoveries have led to the widespread use of new and improved appliances which have made possible higher standards of living for consumers and producers alike.

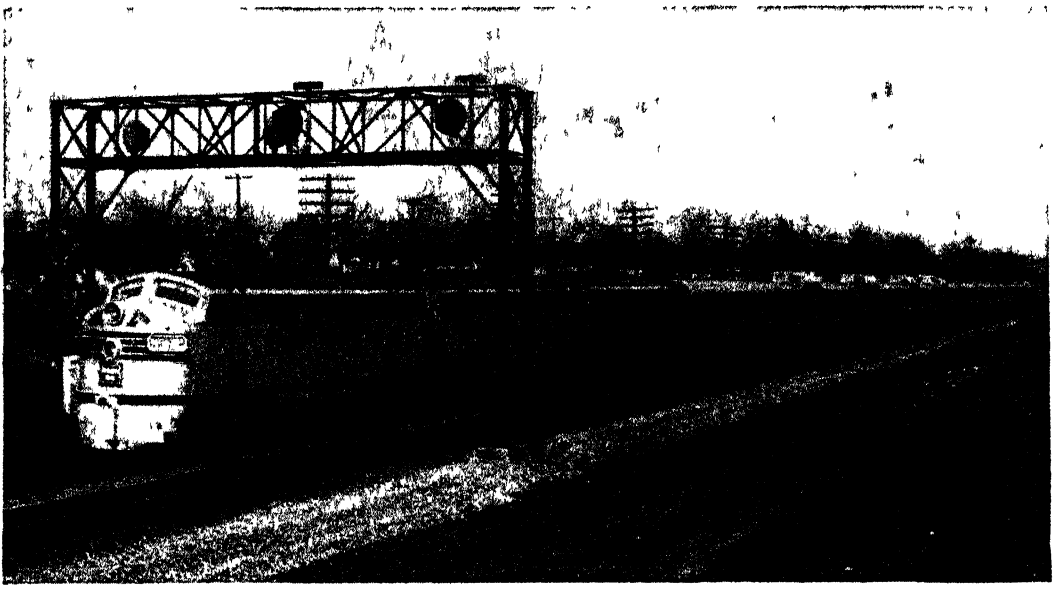
Europe. The electrotechnical industries are well developed in all the leading countries of Europe, notably in England, Germany, France, and Italy, the two first-named being well in the lead. Berlin is normally the foremost center in Germany. Other important German centers are the Ruhr-Rhine region, Saxony, and the cities of Stuttgart and Nurnberg.

England is particularly noted for its manufactures of cables and heavy electrical apparatus. Among the principal centers are the Birmingham, Manchester, and London industrial areas, where power, labor, and markets are all readily available. The Netherlands, Sweden, and Czechoslovakia have become important producers of household electrical equipment.

Exports of electrotechnical products. As a result of the progress of electrification even in relatively remote parts of the world—such as Australia, New Zealand, and Argentina—the international trade in machinery and equipment needed for the production and consumption of electricity has greatly increased in importance. The principal producers also are the principal exporters—the United States, prewar Germany, and the United Kingdom. The exports of the United States are shipped largely to Canada and to Latin America, with the European market, however, not far behind. Germany had its principal market on the continent, while most of the British exports go to other parts of the Empire.

The Transportation Equipment Industries

Equipment with which to move people and goods may quite properly be classed as one of the fundamental material needs of modern man. The stage of industrial civilization attained by any people is indicated by their mode of transportation. Those highest in the scale motor over land and sea or through the air; those lowest in the scale walk on land or paddle their way over sheltered waters in crude canoes. The industrially progressive countries have made great advances in building railroads, steamships, and motor vehicles.



Courtesy Chicago, Burlington & Quincy Railroad

The diesel-powered California Zephyr, America's first Vista Dome transcontinental streamline train, near the end of its 2,532-mile run from San Francisco to Chicago via Salt Lake City and Denver. The manufacture of modern trains for domestic and foreign railroads was one of the great postwar needs. What does the term "vista dome" imply? Where are vista domes most widely used on passenger cars? Why?

In the United States the transportation equipment industries, taken collectively, constitute one of the leading manufacturing groups of the nation. Even if railroad repair shops were not included, they ranked fifth or sixth among the major groups of manufactures at the time of the 1940 census.

During World War II, transportation equipment manufacturing in the United States increased more than any other industry except munitions. In the years of peak production—1943 and 1944—when total manufacturing in the United States was 78 per cent above prewar (1939) production, manufacture of automobiles was up 82 per cent, locomotives 454 per cent, ships 1,669 per cent, aircraft 1,903 per cent, and aircraft engines 2,546 per cent.

Railway equipment. In general, rails are made directly by the rolling mills connected with the larger steel plants and are included among the products of the iron and steel industry. This discussion, therefore, refers only to rolling stock equipment, such as engines, tenders, cars, coaches, and accessories.

Although the railway repair shops are largely service institutions, the larger ones carry on true manufacturing operations and are necessary factors in the success of any railway system. Repair shops, equipped and manned so as to be able to rebuild engines and rolling stock, must be a part of the railway transportation industry whether the country be as highly industrialized as Belgium or as slightly so as Paraguay. In the United States the railroad repair shops constitute an important industry.

Railway equipment is manufactured by the countries which have both large steel industries and important home markets. Such countries are in the most favorable situation to supply equipment to less industrialized countries which have need for railway cars and locomotives. The United States, England, and Germany are examples of the former class, while Mexico, Argentina, and Australia illustrate the latter. As a result of the destruction of rolling stock and factories during World War II, there followed a large postwar demand in France and other European countries for American locomotives and railway cars (see Illus. p. 509).

The motor vehicle industry. The motor car is a European invention which was converted from a luxury product to a common necessity by American mass production through standardized machine methods. Its extensive use has led to results in industry almost revolutionary in scope. Little did those who viewed the French car designed by Panhard in 1894 dream that within the next five decades the motor industry would fill the highways of the United States with its products. The world-wide significance of the motor-car industry is reflected in the fact that on January 1, 1948, there were more than 53,000,000 motor vehicles in use in the world: 39.5 million passenger cars and 13.5 million trucks and busses. Of the total number of vehicles, the United States was credited with 37,883,265 (41 million by 1949), the Soviet Union 3,000,000, Great Britain 2,678,000, France 1,640,000, and Canada 1,786,000. North America and Europe combined account for about 95 per cent of the world's motor cars and for practically the entire motor-car industry—another illustration of the preponderance of these continents in the realm of manufacturing.

The United States, with more than half the world's trucks and more than three-quarters of the world's passenger cars, is the only country where motor-car manufacture is of such tremendous significance that the industrial prosperity of the nation is inseparably connected with it. The American people spend approximately one-tenth of their national income for the purchase and operation of motor cars, this item exceeding every other class of merchandise except that of food and food products. The significance of motor-car manufacturing to various other industries is indicated by the high percentage of their products it consumes: for example, 20 per cent of the steel, 54 per cent of the malleable iron, 80 per cent of the rubber, 43 per cent of the plate glass, 23 per cent of the aluminum, 34 per cent of the lead, and so on. Every state in the Union and many foreign countries supply materials for this industry. A prominent automobile manufacturer has stated that his company alone uses in a year the total output of cotton produced on 433,000 acres, the wool from 800,000 sheep, the leather made from the hides of 30,000 cattle, the hair from 875,000 goats, 500,000 bushels of corn, and the beeswax produced by 93,000,000 honey bees. The economic importance of the motor-car industry to farms, mines, factories, and labor can hardly be overstated.

CENTERS OF AUTOMOBILE MANUFACTURING IN THE UNITED STATES. The earliest automobiles were popularly known as horseless carriages. Prior to the motor-car age, the most successful centers for the manufacture of wagons and buggies had developed in the eastern part of the great grain-growing belt, where raw materials of softwood, hardwood, iron and steel, power resources, labor, and markets in the fast-growing prairie farmlands were all at hand. Michigan, Wisconsin, Indiana, and Ohio had already developed prosperous wagon and carriage factories.

When motors, particularly internal combustion engines, were applied to locomotion it was natural that they should first be mounted on carriages, and it was equally natural that carriage makers and motor makers should combine their plants. Some of the well-known carriage makers who turned early to automobile manufacture were Haynes, Mitchell, Olds, and Studebaker. A few firms still carry proudly on the flags above their factories the names of their pioneer wagon makers. The centers of manufacture remain in the states which were leaders in the carriage industry.

The manufacture of motor cars thus is distinctly localized. In 1939 about half of all the wage earners in the motor-car industry were employed in Michigan; Ohio was second with about one-eighth, followed in turn by Indiana, New York, Wisconsin, and other states. In recent years there has been a tendency toward the building of automobile assembly plants in several cities in the west so as to save shipping space and reduce costs.

Courtesy United Air Lines

United Airlines Douglas DC-6 *Mainliner 300* in flight. At about what speed per hour do modern commercial air ships travel?

Trends of trade. The motor-car industry is essentially a development of the present century. The census reported only 4,192 cars and trucks made in the fiscal year ending June 30, 1900. At first, growth was slow; the annual output did not reach the 100,000 mark until 1909, and the 1,000,000 mark was first exceeded in 1916. Since 1922, in every year except 1932, 1933, and the four war years, the 2,000,000 figure has been exceeded, and in 1929, production reached 5,358,420 motor vehicles, a figure not again approached until 20 years later. It seems clear that, although the period of rapid expansion may be over, the motor-car industry will continue to hold a position of front-rank importance in the economic life of the nation.

Foreign trade. The drop in exports of American automobiles following 1929 was even greater than in many other lines. The people of importing countries apparently still consider motor cars as luxuries; in periods of economic adversity, trade in luxury articles suffers more than trade in articles essential for carrying on the customary activities of life. In 1929 the total value of motor cars, parts, and accessories exported was $557,000,000; in 1932, it dropped to $83,000,000. Recovery was rapid, and in 1947 peacetime exports passed the billion-dollar mark for the first time. In 1944, war exports of motor vehicles for military use reached the fantastic total of $5,297,917,000. Before the war, value of passenger car exports was about twice as great as that of trucks. Since the war, truck exports have predominated.

Before World War II Canada was easily our largest foreign customer for automobiles, followed by the Union of South Africa, Argentina, Brazil, Mexico, and northwestern European countries. In 1947 Argentina was the largest buyer, followed successively by Brazil, Canada, Mexico, South Africa, and Belgium.

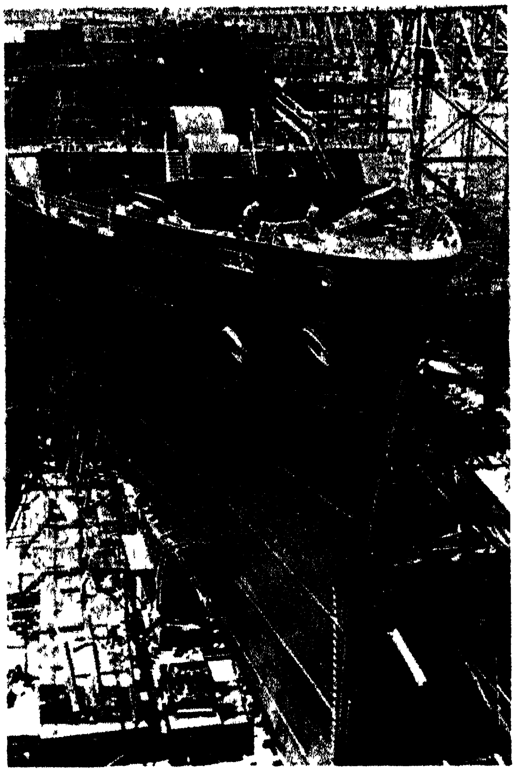
The aircraft industries. Since the first successful flight in a powered plane, made by Wilbur and Orville Wright in 1903, aircraft production has alternated between boom periods, occasioned by military demand, and relatively slack periods. The first commercial sale was made in 1909 by the Wright brothers to the United States Army. World War I became the first extensive proving ground, leading to important improvements in aircraft design. After that war, commercial use of the plane expanded until now most parts of the world are served by commercial lines. Aircraft have developed from the early wood-wire-and-cloth biplanes to the modern aluminum monoplanes, and weight of aircraft engines has been reduced from nearly 16 pounds per horsepower for the *Kitty Hawk* to one pound per horsepower for modern planes (see Illus. p. 511).

All modern industrial countries are engaged in aircraft manufacture, but in none has output been as great as in the United States. The number of wage earners engaged in the manufacture of aircraft and parts in this country was 3,543 in 1919, 14,710 in 1929, and 62,000 in 1939. In 1939, 279 million dollars' worth of planes and parts were produced. In 1940, President Roosevelt issued his call for an annual production of 50,000 planes, an "impossible" figure. By 1943 production-worker employment in the manufacture of aircraft and parts was 1,903 per cent above that of 1939, and employment in production of aircraft motors was up 2,526 per cent. In all, the wartime production amounted to 300,000 planes. Though production after the war dropped far below its wartime peak, the production-worker index in the aircraft industry in 1946 still was three times as high as in 1939.

GEOGRAPHICAL DISTRIBUTION OF AIRCRAFT INDUSTRIES. The manufacture of aircraft and aircraft parts is widely distributed in the United States. Because it lacked dependence upon bulky raw materials, this latecomer on the industrial scene did not have to confine itself to existing industrial centers which had specified characteristics. Early aircraft centers, it is true, were in the industrial east, and even at the beginning of the great expansion in 1940 Baltimore and Buffalo still were major centers of the industry. Los Angeles and its satellite cities, however, had also become a leading center, favored by the mild weather that permitted flight testing of planes at all seasons. In the expansion associated with World War II, the government encouraged the establishment of new plants throughout the heart of the country instead of along the more exposed coasts and financed new plants at such places as Fort Worth, Tulsa, Kansas City, and Omaha. Other important plants are at St. Louis, Wichita, Seattle, and several smaller cities. The aircraft motor industry has remained concentrated largely in the northeast, at Cincinnati, Indianapolis, and other towns from Muskegon, Michigan, to East Hartford, Connecticut.

The large size of modern planes does not lend itself well to compact settled assembly lines such as exist in the automobile industry. As a result, plane manufacture is done by means of many sub-assemblies, sometimes from different plants, and a final master-assembly into the completed plane. The rapid development of improved designs and the competition of commercial airlines to outdo each other with bigger, faster planes make aircraft manufacturing a highly competitive, fluid industry.

Export trade. American export trade in aircraft and accessories is an important phase of the industry. Latin America is ordinarily the foremost market for commercial planes owing to its need, its nearness, and its contacts with American producers. Aircraft service is a highly practical means of transport and communication for the countries beyond the Rio Grande because of their vast areas not serviced by railroads or motor highways, and we may expect this trade to become increasingly important in the years ahead.



Courtesy U S Maritime Commission

Bow of the steamship *America*, largest ship of the American merchant marine to date, under construction in the shipyards at Newport News, Virginia. Although new yards were built during World War II at other southern and western ports, Newport News and the great shipyards at Brooklyn and along the Delaware River have retained their earlier importance.

The boat and shipbuilding industries. Boats were perhaps the earliest vehicular means of transportation built by man, and water transportation remains one of the foremost means of haulage, and also usually the most economical. However, until quite recently boats were small and slow-moving; even steamships were of comparatively small size until the latter part of the nineteenth century. During the past four decades great strides forward have been made in size, speed, and efficiency.

The tonnage of the merchant marine fleet of the world furnishes a fairly accurate index of the shipbuilding industry. The accompanying table presents the situation just before and just after the war. It is apparent that the rank of the United States and Britain was reversed during the war, and that in proportion to area and population, the Norwegians, Swedish, and Dutch are leaders as seafaring people. The importance of the shipbuilding industry is, in general, proportionate to the importance of the ocean shipping of a nation.

Shipbuilding in the United States. Water transportation in this country involves lakes, rivers, coastal waters, and the

TABLE XVII

MERCHANT MARINE OF THE WORLD AND OF LEADING COUNTRIES BEFORE AND AFTER WORLD WAR II

(gross tons, 000 omitted)

	1939	*1946*
World	58,270	71,000
British Empire	17,770	18,064
United States	8,125	35,363
Japan	5,102	1,086
Norway	4,149	2,934
Germany	3,916	800
Italy	3,178	576
France	2,678	1,371
Netherlands	2,670	1,591
Greece	1,698	619
Sweden	1,312	1,438
U S S R	1,136	1,852
Denmark	1,042	641

Source: U S. Maritime Commission.

open ocean. The importance of the Great Lakes shipping is indicated by the fact that the Detroit River is the busiest canal in the world, handling six times as much traffic as the Panama Canal; and Duluth-Superior is second only to New York among American ports in volume of shipping. Ships also ply the larger rivers, and others serve the seaports. An important boat and shipbuilding industry has developed to provide vessels and service docks for these transportation lines.

Since shipyards for building seagoing vessels must be located adjacent to deep water, they are generally constructed at or near large shipping ports. Other geographic factors of importance are availability of labor and of the materials necessary for construction, especially steel. In the United States the largest centers are at Quincy, Massachusetts; Kearney and Camden, New Jersey; Chester, Pennsylvania; and Newport News, Virginia (see Illus. p. 529). There are also important shipyards on the Pacific, Gulf, and south Atlantic coasts. During World War II, Portland, Oregon, added a shipbuilding industry with a payroll of 100,000 workers. As with airplanes, shipbuilding was increased prodigiously during the war, over 100,000 new ships, of all types, having been produced.

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Chapter Twenty-nine

TRANSPORTATION AND COMMERCE

If you live in the northeastern United States, every time you buy an orange from California nearly half the price you pay represents the cost of transporting the orange from California to your grocery store If the orange comes from Florida, about one-third of the price represents transportation costs. The only way to avoid paying the railroad fare for the orange is to live near an orange grove in California, Florida, or Texas. Then you would have to pay the cost of shipping your shoes from Boston, your new automobile from Detroit, and your automobile tires from Ohio. In modern civilization, the costs of transportation cannot be escaped, but the real benefits of transportation can be enjoyed. Without a good transportation system, the northeasterner would not be able to eat oranges and enjoy the countless other consumer goods that are brought from a distance to feed, clothe, shelter, and amuse him. Furthermore it would not be economically possible to have large orange groves at the producing end of the line.

Importance of transportation to regional specialization. Geographically, then, a major significance of transportation is the fact that it enables areas to specialize in production and to exchange their products for other goods in which other areas specialize. This geographical division of labor permits large-scale production and sale of crops, minerals, lumber, and manufactured products at much lower costs than would be possible if every family or every physical or biological region tried to be self-sufficient. The existence of a modern city would be impossible without some way of shipping out and selling the manufactures or services of the city and shipping in food, clothing, and building materials from outside.

By tying together the diverse rural and urban landscapes which it helped create, the transportation system makes a whole nation and to a considerable extent the whole world into a single market. The United States is an outstanding example of the economic and cultural "unity through diversity" brought about by an excellent transportation system.

If the transportation system has induced more people to concentrate in cities, it has at the same time permitted decentralization of city workers into suburban homes, and has ended the proverbial isolation of rural life. The automobile, for example, has increased the range and speed of the country doctor. It also has improved school facilities by making possible bus-served consolidated schools, thus bringing the advantage of division of labor in teaching to small communities that otherwise could not have afforded it.

The utter dependence of modern states upon the transportation system is brought into sharp focus during wartime. In World War II, for example, the military planning of the United Nations both in the West and in the Orient was directed first toward destruction of the means of transportation of the enemy. For example, the Normandy invasion was preceded by weeks of ceaseless bombing of enemy airfields, railroad marshaling yards and bridges, and highway bridges, and by months of bombing aircraft and ball-bearing factories, oil storage facilities and refining plants, essential for construction and fueling of vehicles. When the invasion finally occurred, the enemy was unable to move swiftly and so rearrange his troops as to meet the shifting threats of the new front. Similarly, before the knockout blow in the Orient, Japan had been gradually brought to her knees by the relentless campaign of submarines and airplanes, to the point where she no longer had the merchant shipping so vital for her economic life and war activity.

Courtesy U. S. Maritime Commission.

Where rail and water meet, at Weehawken on the New Jersey side of the lower Hudson River. A part of the facilities that give the port of New York its shipping capacity of 1,900 carloads per day.

Transportation as an element of the landscape and of economic life. Besides their importance in the regional development of the world, the forms of transportation are themselves important features in the culture landscape of the geographic scene. The railroad tracks and yards, the ribbons of highway, the huge surfaces of airfields, the conspicuous petroleum tank farms, and the lines of docks and warehouses of the great ports, are as truly a part of the earth's surface today as the vegetation, land forms, cultivated fields, and houses (see Illus. p. 516).

At least one out of every seven people in the United States earns his living from the transportation industry and its supporting industries. In 1947, for example, automobile manufacturing employed 2,369,985 people, railroads 1,352,000, automobile sales and servicing 1,310,724. Additional millions are employed as truck drivers, petroleum refinery workers, producers of steel and other raw materials used in automobile manufacture, highway workers, and airplane factories. The ramifications of the transportation industry are indeed extensive.

Photo by Mary Light, in R U Light Focus of Africa, American Geographical Society

Primitive transportation Women at Juba, Anglo-Egyptian Sudan, carrying charcoal to market.

Along with consideration of the transportation systems themselves, we will pay brief attention to the development of commerce and trade with which the systems are inextricably linked.

Forms of Transportation

The principal forms of transportation in the modern world are railways, waterways, pipe lines, highways, and airways. Each of these forms is used for interregional transport within one nation and for transport between nations, and each (except pipe lines) carries both freight and passengers. Waterways are of the inland type—rivers, lakes, and canals—and of the ocean type. Highways in the broadest sense include trails as well as roads for wheeled vehicles, though today in the United States, highway traffic is commonly thought of as automobile traffic.

Relative importance of different forms of transportation. The relative importance of the various forms of transportation is constantly shifting in the course of time and also differs greatly between different geographic regions at a given time.

Of four or five great historic shifts that have occurred in the prevailing form of transportation since man depended entirely upon his own back for carrying loads (see Illus. at left), two began before the Christian era, one has taken place within the past hundred years, and one within the past forty years in the United States. A fifth is just getting well under way.

Animal power. The ultimate in streamlined modern land transportation in one of the most advanced countries of the world, Egypt, around 3,000 B.C. was the donkey. Some geniuses had succeeded in domesticating wild donkeys, and in developing harness by means of which a donkey could carry a load twice as heavy as could a human porter. Furthermore, one man could manage a train of several donkeys, thereby multiply manyfold the means of transporting products. The use of animal power developed early in southwestern Asia, too, and larger animals such as horses and camels were trained, but the idea spread slowly to the rest of the world (see Illus. p. 518). Even 4,500 years later, when Columbus arrived in America, the American Indians were still depending largely upon human power for transportation. The Incas had the llama as a beast of burden, and the Eskimos had dog sleds, but most Indians, including even the Aztecs, had no animal transport.

A second great stride in transportation was the application of animal power to wheeled vehicles. An animal can pull several times as heavy a load with a cart or wagon as it can carry on its back. The first known use of wheeled vehicles was for war. The Hyksos, with the advantage of possessing the horse-drawn war chariot, were able to conquer Egypt between 1700 and 1600 B.C. Shortly thereafter, wheeled carts were being used to haul produce. The use of carts gradually spread to more and more distant areas and was adapted to other types of animals. In England as late as 500 B.C. solid-wheeled carts still were being pulled by laboring oxen; there were then no paved roads.

Photo by E. Gyger, Courtesy Official Information Bureau of Switzerland.

Mule train delivering mail, Lotschen Valley, Switzerland. Animals can travel on steeper, narrower, and cheaper roads than automobiles or railroad trains, and therefore remain important means of transportation in many mountainous areas.

The railroad era. For 2,500 years after their introduction to Egypt, animal-powered vehicles continued to be the most advanced form of land transportation of freight. Where waterways were available, land vehicles could not compete for bulk freight with boats using wind or animal (towing) power. Then, a few decades after the creation of an independent United States, there occurred a third and in some ways the most profound revolution in transportation: the application of machine power to wheeled vehicles. The first locomotive to run on rails was built in England by Richard Trevithick in 1804. Then followed a series of small coal-hauling lines from individual mines. In 1825 the Stockton and Darlington Railroad, the first public carrier steam railroad, was built by George Stephenson and opened for business. Its main purpose was to haul coal 12 miles from Darlington to Stockton, a port on the River Tees, for export.

In the United States, the prime stimulus for railroad building was the eagerness of Atlantic coastal ports for adequate connection with the rapidly developing lands west of the Appalachians. Baltimore took the lead, and the founding of the Baltimore and Ohio Railroad in 1827 marked the start of the American railroad system. By 1830 the first locomotive was in operation on this railroad (see Illus. p. 338); by 1842 the coal fields of Cumberland, Maryland, were tapped by the rails advancing along the Potomac River; by 1852 the Ohio River at Wheeling, West Virginia, was reached; and by 1857 the line reached the Mississippi at St. Louis. Other lines were being vigorously pushed, and by the beginning of the Civil War the railroads were major factors of transportation, with 30,000 miles in the United States. In 1869 for the first time the Atlantic and Pacific were connected by rail, with the closing of the last gap in the Union Pacific Railroad. By 1893, when the Great Northern Railway reached Puget

Sound from the East, the framework of the American railroad system was complete, with 176,461 miles of road owned. The additional miles of road added since then have been largely a filling in of the detail of the framework. The peak length of the railroads was 254,036 miles, attained in 1916. There has been a slow reduction in length of about 11 per cent since then. The United States leads the world in volume of railroad freight traffic per capita. In 1938, such traffic amounted to 11.8 tons per capita. In comparison, Canada, Australia, and northwestern Europe averaged 5 to 7 tons per capita; Argentina and the U. S. S. R., 3; Yugoslavia and Romania, 1 to 2; India, 0.34; and China, 0.07 tons.

The rise of automobiles. The invention of the internal-combustion gasoline engine resulted in the development and astonishingly rapid multiplication of those ubiquitous, self-propelled vehicles known as automobiles. Nowhere in the world has the rise of the automobile been so great as in the United States. In 1895 this country had a total of four registered motor vehicles. Thirty years later we were definitely in the era of automobile passenger transportation. The accompanying figures in the table indicate the rapidity of the increase:

Year, Dec. 31	*Number of Registrations of Privately Owned Automobiles* (to nearest thousand)
1900	8,000
1905	79,000
1910	469,000
1915	2,491,000
1920	9,239,000
1925	19,941,000
1930	26,532,000
1935	26,230,000
1940	32,035,000
1945	30,638,000
1948	41,038,000

Source: Bureau of the Census: *Statistical Abstract of the United States*, 1948; Automobile Manufacturers Association: *Automobile Facts and Figures* (figure for 1948)

Along with the widespread ownership of automobiles came a tremendous program of highway building and improvement. The transportation pattern and habits of the country were profoundly affected. The rest of the world, too, has experienced important development of highway transport, though 7 of every 10 automobiles in the world today are in the United States. Today there is about one automobile for every 4 people in the United States, compared with one for 7 people in Canada, 17 in Great Britain, 25 in France, 70 in the Soviet Union, 96 in Mexico, 140 in Czechoslovakia, 144 in Italy, 1,752 in India, and 15,367 in China.

The rise of airplanes. Gasoline engines soon (in 1903, at Kitty Hawk) proved to be light enough to bring to reality the age-old dream of flying in self-propelled heavier-than-air vehicles. Though air traffic still represents only a small portion of the total volume of passenger, freight, express, and mail traffic today, the rate of increase in all these categories has been phenomenal. Passenger and mail traffic has become definitely important. It is hard to realize that as late as 1926 there was no international passenger traffic carried by American airlines, and only 5,782 passengers were flown by our domestic lines during that year. The first year with more than one million domestic airline passengers was 1936. The largest upsurge occurred after World War II: in 1944 there were 4½ million domestic airline passengers; in 1947, 13,189,366 revenue passengers, and 6½ billion passenger miles were flown. The accompanying table reflects, in terms of freight and passengers hauled, the relative standing of the five main forms of transportation in the United States in the last "normal" year and shows the principal trends of the past 30 years.

The most striking change shown by the table during the 23-year period covered was the percentage shift in passenger traffic from railways to highways. From negligible amounts in 1916, automobiles jumped to over 90 per cent of the passenger traffic

TABLE XVIII

ESTIMATED INLAND INTERCITY TRAFFIC

	Freight Per cent of total ton-miles		*Passenger Per cent of total passenger-miles*	
	1916	1939	1916	1939
Railways	77.2	62.6	98.0	8.6
Steam	77.0	62.5	82.1	8.3
Electric	0.2	0.1	15.9	0.3
Inland waterways	18.4	17.9	2.0	0.5
Great Lakes	17.3	14.2	0.9	0.3
Rivers and canals	1.1	3.7	1.1	0.2
Petroleum trunk pipe lines	4.4	9.5	—	—
Crude	4.4	8.8	—	—
Refined	—	0.7	—	—
Highways	*	10.0	*	90.7
Airways	*	0.0	*	0.2
	100.0	100.0	100.0	100.0

* Negligible.
— None
Data from National Resources Planning Board: *Transportation and National Policy.*

in 1939, while rail passenger traffic dropped from 98 per cent in 1916 to 8.6 per cent in 1939. There were 249 billion automobile passenger miles traveled in 1939 compared with about 23 billion passenger miles for railroads. Passenger traffic on waterways, already small, declined still further: most passengers want speed. Airplanes had just entered the statistical picture. By 1947, the relative position of the different types of carrier was the same, except that air traffic had shot ahead of waterway traffic, though still amounting to only one-seventh as much as railway traffic.

During World War II, rail passenger traffic quadrupled the 1939 figure; by 1947, it had fallen back some, though it was still double 1939. On the other hand, automobile traffic declined during the war, owing to restrictions on consumption of gasoline for civilian uses. By 1946, it had regained prewar levels, as gasoline restrictions eased and new cars began to appear in some abundance.

In freight movement, the basic geographic phase of transportation, the railroads have easily maintained their pre-eminent position over all other forms of transportation combined. Under the pressure of war needs, rail freight tonnage more than doubled during the war, and in the early postwar period it remained considerably higher than in 1939. The inland waterways kept their position in second place, although their freight had slowly declined about 5 per cent by 1946. Pipe lines doubled their percentage of the national haul between 1916 and 1939, and afterward maintained a steady increase. Highway trucks were slightly ahead of pipe lines in volume of freight in 1939. Airways freight haulage was and still is very small but growing.

Comparative economic-geographic advantages of transport forms. As new forms of transportation have arisen, they have only partly replaced the older forms. All the older forms of transportation persist in some parts of the world, most of them even in some parts of the United States. Pack donkeys are still widely used in our own southwest. Horse-drawn vehicles still are common in many American farming districts. In the Old World and Latin America there are vast areas without highways and railroads; some of these areas still use human porters for moving freight, while others use airplanes extensively.

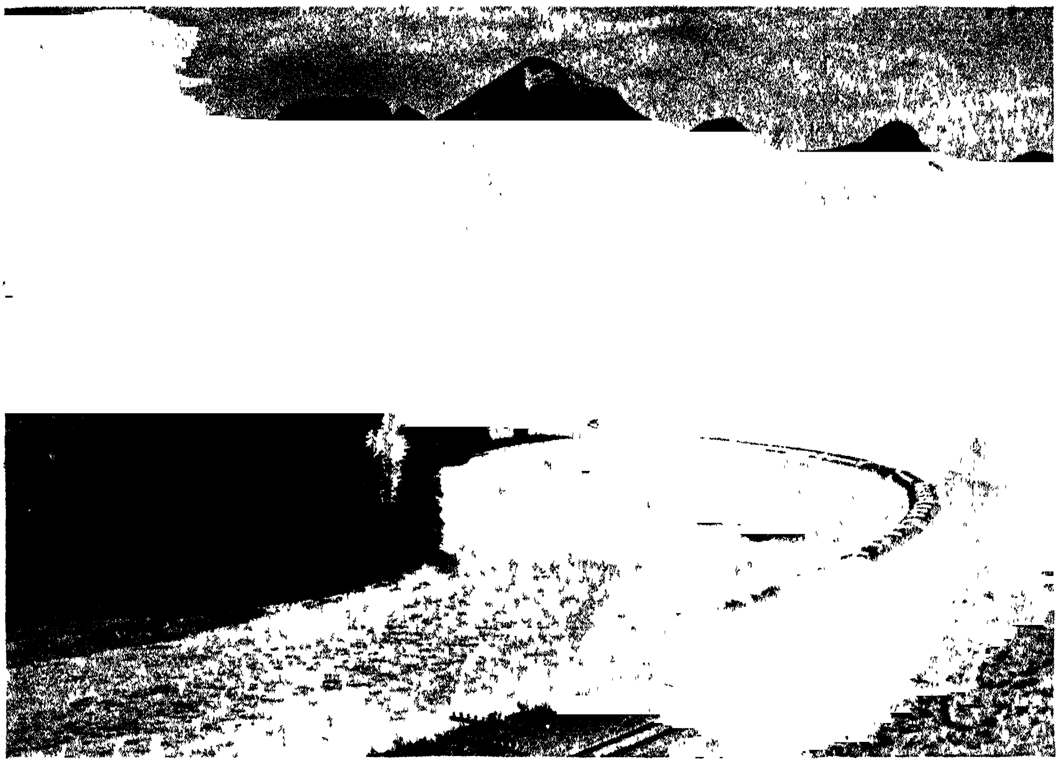
Before looking at the picture of world distribution of transportation systems, it would be well to consider what factors enter into the decision to develop one or another form. To some extent the retention of older forms of transportation may be the result of lack of adequate capital for constructing the modern type. Another reason may be that the fundamental need for large-scale transportation does not exist: that is, there may not be resources or population so located as to generate traffic in the area. Modern forms would then be prohibitively costly. Physical features may strongly favor one as against another form of transportation. The terrain, such as the steepness of slopes; and the climate, particularly the visibility, precipitation, and coldness of winter, may encourage or completely prevent the use of certain kinds of transportation. Each form of transport, from donkey to airplane, has its own peculiar advantages and disadvantages, and each is useful in certain areas and under some conditions

Terrain and transportation. The configuration of the land profoundly affects the types of transportation that can be used in a given area

Boats require the most level terrain. Ocean transport, of course, utilizes the sea-level plane of water; inland waterways can be developed only where nearly horizontal streams and canals are possible. Even a low range of hills may completely bar the use of waterways. By the use of locks, a series of successive "steps" of water can be created for climbing slopes, but slowness and expense prohibit the use of these for great elevations Even the Panama Canal, with its famous and costly locks, at no point has its floor higher than 40 feet above sea level

Existence of natural or improvable termini, or harbors, is the critical factor of terrain for sea or lake transport.

Railroads are limited to fairly gentle slopes, and the avoidance of steep grades is the principal technical requirement in lay-



Courtesy Canadian Pacific Railroad Company

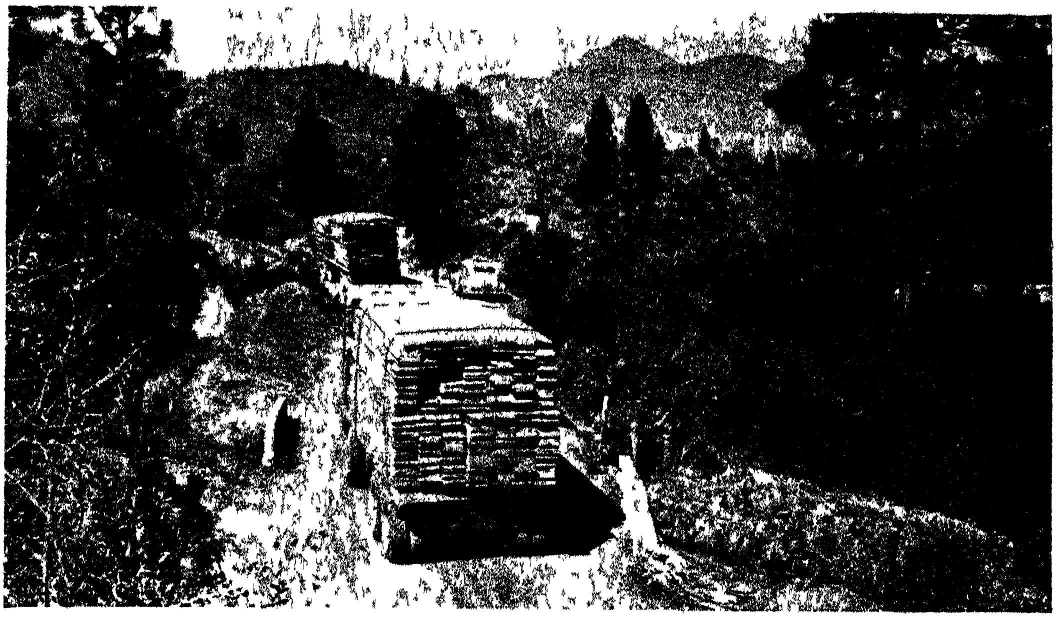
Winding through the Canadian Rockies west of Banff, Alberta In mountainous areas, railroads follow stream-graded valleys wherever possible Steam engines constitute more than 85 per cent of American locomotives on Class I railroads today Railroads help develop three great Western resources shown here—timber, water power, and scenery These resources, in return, support the railroads ing out rail routes. On a 1 per cent grade (a grade that rises 1 foot for every 100 feet of horizontal distance) a locomotive can pull only one-fifth as heavy a load as on the level. The maximum grade of the transcontinental lines through the Rockies is 2.2 per cent. The maximum grade of any through line in the Great Smokies is 4.7 per cent. Even the Peruvian Central, which climbs the Andes to an altitude of 15,806 feet, the highest point on any standard-gauge railroad in the world, has no grade steeper than 4 per cent.

Courtesy Official Information Bureau of Switzerland

Electric railroad in the Alps between St. Moritz, Switzerland, and Tirano, Italy. The glacier in the background is a reminder of the height of the mountain passes and tunnels.

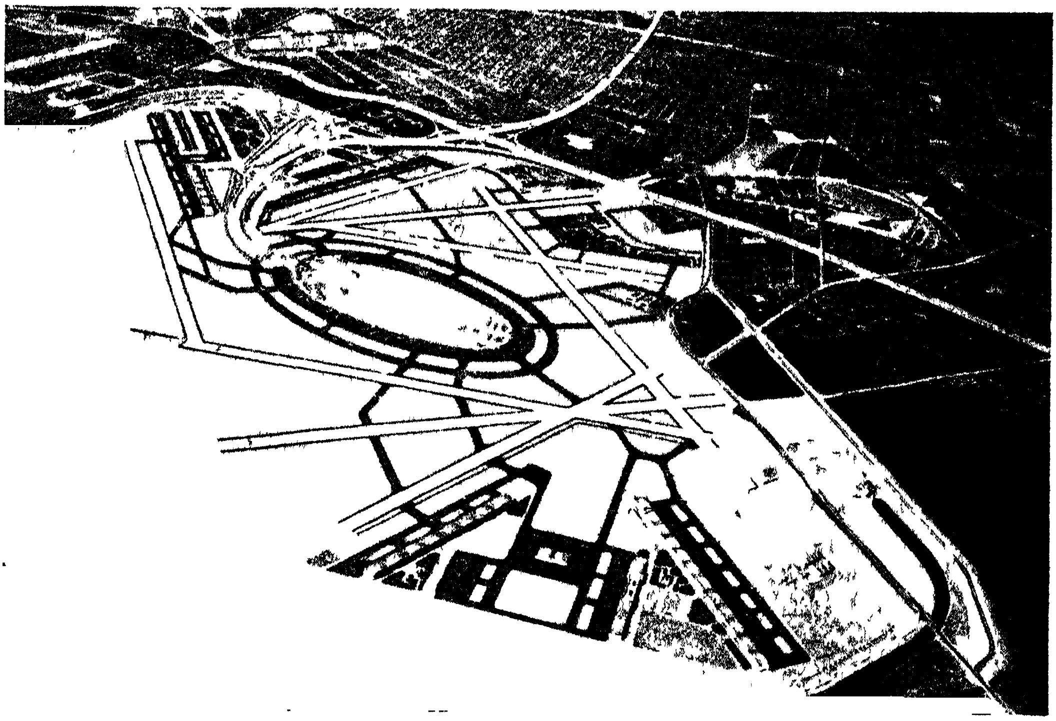
In order to secure minimum grades, railroad routes are selected so as to avoid mountains as much as possible, by using lowlands or following along the courses of naturally graded streams (see Illus. p. 521). Where mountains cannot be avoided, it is necessary to carry the grade across canyons by building numerous bridges and trestles or constructing tunnels through the mountains (see Illus. below). The Alps, in the very center of trading pressures from Germany, France, Italy, and Austria, have 16 of the 27 longest tunnels of the world, including the longest one of all, the Simplon tunnel 12.3 miles long, on the Swiss-Italian border. Such structures add greatly to the initial cost of railroad construction, and only voluminous traffic would justify their construction.

Another feature of terrain that interposes serious and sometimes impassable barriers to railroads is water, in the form of rivers, lakes, or swamps. Narrow or shallow water bodies can be bridged, but large ones can only be ferried or avoided. Chicago is the classic example of a city which developed at a turning point of a great lake.



Courtesy Automotive Safety Foundation

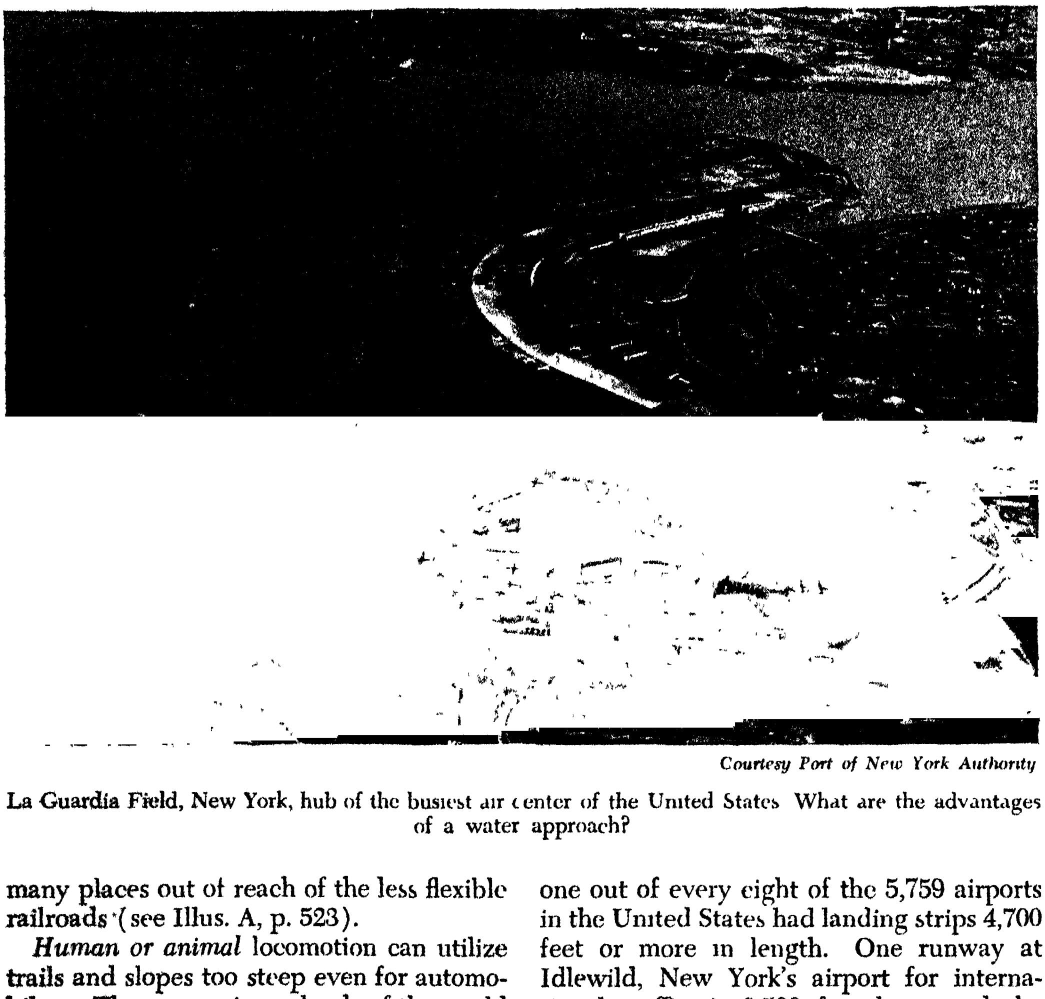
(A) Freighting by truck on a mountain road in California Building operations in the mountains and railroad traffic in the lowlands are fed by such modest links



Sketch by A Leydenfrost Courtesy Port of New York Authority

(B) New York International Airport (Idlewild), largest commercial airport in the world, as planned Why does it need a runway nearly two miles long?

Automobiles, with their ability to shift gear, can climb much steeper gradients than can locomotives. Even trunk highways rise and fall at gradients that would require trestles and deep cuts or tunnels for railroads. In mountainous country, roads can penetrate into areas entirely inaccessible to railroads. In addition, the cheaper cost of building simple roads gives trucks access to many places out of reach of the less flexible railroads (see Illus. A, p. 523).



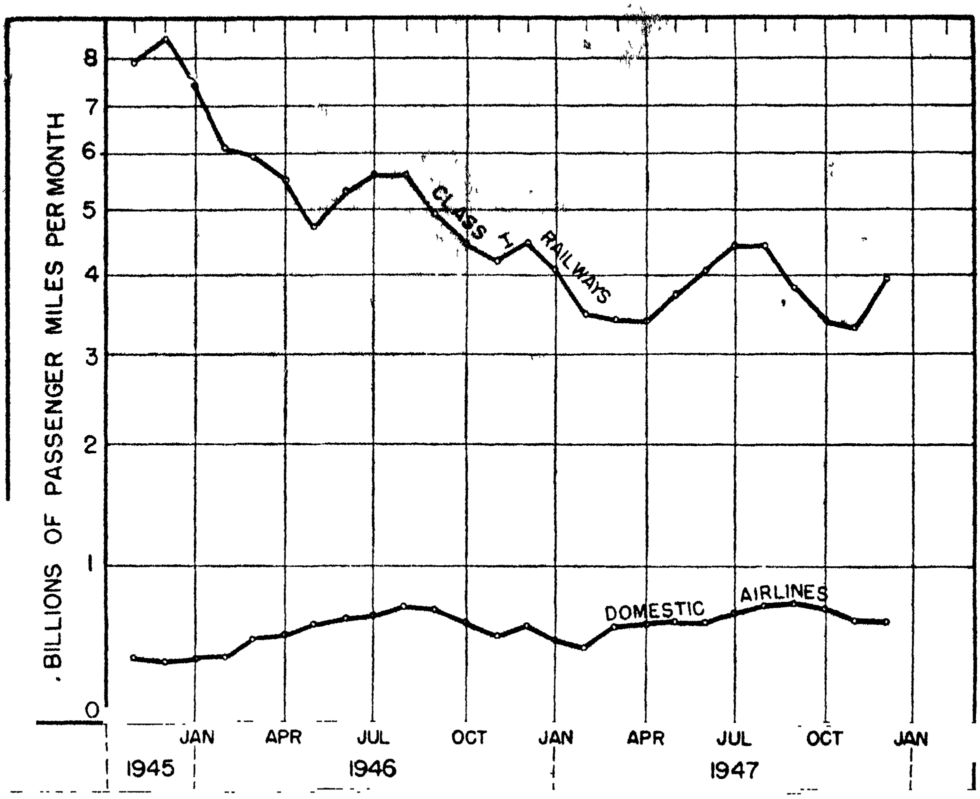
Courtesy Port of New York Authority

La Guardia Field, New York, hub of the busiest air center of the United States What are the advantages of a water approach?

Human or animal locomotion can utilize trails and slopes too steep even for automobiles. The mountainous lands of the world have remained a stronghold where pack animals such as donkeys, mules, horses, llamas, and yaks have not been displaced by mechanical power transport (see Illus. p. 518).

Airplanes are more independent of terrain conditions of their routes than is any other form of transportation. Steepness of slope, bogginess of ground, and depth of sand along the line of flight are alike inconsequential to these soaring vehicles. The critical terrain factor for airlines, as for ocean transport, is the character of the terminal area. A long, flat piece of land is essential for take-off and landing. In 1948, one out of every eight of the 5,759 airports in the United States had landing strips 4,700 feet or more in length. One runway at Idlewild, New York's airport for international traffic, is 9,500 feet long, and the entire field covers 7 square miles (see Illus. B, p. 523). In addition, the terrain must be low for a considerable distance beyond the ends of the airfield, because airplanes (except helicopters) can rise from the ground only at a rate of about 1 in 20 (a slope of

5 per cent), and 1 in 30 is usually provided to allow for possible failure of one motor during take-off. For many cities it is a difficult problem to find a level piece of ground large enough for an airport. Coastal cities often can reclaim flat stretches of unused marshland. Thus, New York reclaimed the mud flats of Flushing Bay on the north side of Long Island for La Guardia Field (see Illus. p. 524), the sandy flats on the south side of Long Island for the Idlewild Field. Water provides unobstructed approaches for both fields. In parts of the Appalachians, it is impossible to find adequate flat lands.



A two-year record of passenger traffic. Note the regular winter declines in air traffic, and the December and summer bulges in rail traffic. The general postwar leveling off of rail traffic and increase of air traffic is apparent.

Climate and transportation. Dependability is an important characteristic of transportation. Climate and weather affect to varying degrees the dependability and, in some instances, even the possibility of existence of some forms of transportation.

Waterways of course depend upon the existence of enough water for navigation. Dry climates are obviously not ideal for waterways fed by inland water. The Suez Canal runs through a desert, but its water comes from the Mediterranean at sea level. The Panama Canal, on the other hand, obtains its water from a tropical river. Where a river is seasonally low, like the Nile, Indus, or Sacramento, navigation must stop or diminish during the dry season unless some form of artificial storage of water is adopted, by means of dams such as those of Aswan and Shasta.

Cold winters also seasonally prevent navigation of waterways. Rivers like the Yukon, Mackenzie, and Yenisei can be navigated only after the spring melt of the frozen surface. The New York Barge Canal (successor to the Erie Canal) usually closes about December 1 and opens again about April 1, though the exact date varies from year to year. The northern and southern portions of the oceans are seriously affected by ice fields and scattered icebergs in winter and spring. The main steamship route across the North Atlantic has to be shifted some years because of this polar ice. Regular navigation along the Northwest Passage (Arctic coast of North America) is prevented by ice, and regular navigation along the Northeast Passage (Northern Sea Route) along Asia is conducted for only a brief period in summer.

Weather conditions at the terminals, especially at the time of landing, are more important to *air transport* than are conditions along the route. Visibility is the most important single weather element for airplanes. If dense fog, low cloud, or falling snow makes the landing field invisible, commercial planes ordinarily stay on the ground or, if already in the air, seek a different field for landing. Modern radio telecommunication makes it possible for a plane in flight to be directed to an open airport. Eventually fog dissipation or blind landings made with special guidance may become widespread, but in the winter of 1948-1949 cancellation of flights owing to weather was still the chief annoyance of winter flying. The graph on page 525 shows the distinct winter drop in air traffic for two representative years.

The question of safety frequently is raised in connection with air transportation. As a result of cautious operation by the airline companies, stringent regulation by the government, and the improvement of planes and navigation aids such as radio beacons, the number of accidents on scheduled flights has been reduced to a low figure. The number of passenger fatalities per 100 million passenger-miles by different means of transportation for two years a decade apart is contained in the following figures:

	1934-35	*1944*
Railroad trains	0.24	0.26
Public carrier busses	0.64	0.22
Passenger cars and taxis	5.3	2.9
Scheduled airlines	5.8	2.12

Source: Actuarial Society of America, *Report of Committee on Aviation;* and Air Transport Association of America.

Air fatalities were more numerous proportionately than those of trains and busses, but somewhat fewer than those of private automobiles. Weather was responsible for about one-fifth of the airplane accidents. In number of nonfatal injuries, airlines would make a better showing, because airplane accidents are more likely to be fatal than train or passenger car accidents. Furthermore, in 1944 automobiles made an abnormally good showing because of wartime restrictions on gasoline and speed. Although railroads consistently show lowest number of fatalities, all the forms of transportation give you a chance of better than 20 million to one of reaching the end of a given mile alive.

Highway traffic may be slowed or temporarily blocked by snowfall and by glaze in lands of snowy winters. In severe snowstorms, snowplows may be unable to keep even the main highways open. In thinly settled areas like northern Canada and northern Russia, the people change their forms of transportation seasonally in accordance with the condition of the ground. Sleighs drawn by horses are widely used on the snow-covered roads and on the frozen rivers. Sledges drawn by dogs or reindeer are used by the native people of the far north in Europe, Asia, and North America. Icy glaze is responsible for accidents and delays due to skidding.

In areas with cold winters, all roads unless well-paved are subjected to alternate freezing and thawing, especially in spring. This process wreaks havoc with dirt roads and other roads not substantially paved, and necessitates the expenditure of large sums for upkeep every year.

In desert areas, wind-blown sand sometimes obstructs traffic on roads much as snow does in winter. Gullying and washouts may damage highways in any climate, and landslides often close highways temporarily in mountainous country, particularly after a heavy rain or thaw saturates and loosens large masses of earth and rock.

Railroads represent the most dependable form of inland transportation at all seasons and under all weather conditions. Their safety record is suggested in the tabulation of fatalities given on page 526. Skidding on icy roads, getting lost or missing a terminal in a heavy fog, and falling dangerously in an air downdraft, need not worry a train. The most troublesome weather element is snow, and snow usually can be removed from tracks by powerful snow plows. (see Illus. above). In the Sierra Nevada, where snowfall sometimes amounts to 40 feet in a season outside of drifts, special protection for trains is given in some mountain passes in the form of miles of snowsheds built over the tracks. For highways, no attempt is made in many mountain passes to keep the route open in winter. Landslides in mountainous areas sometimes block traffic.

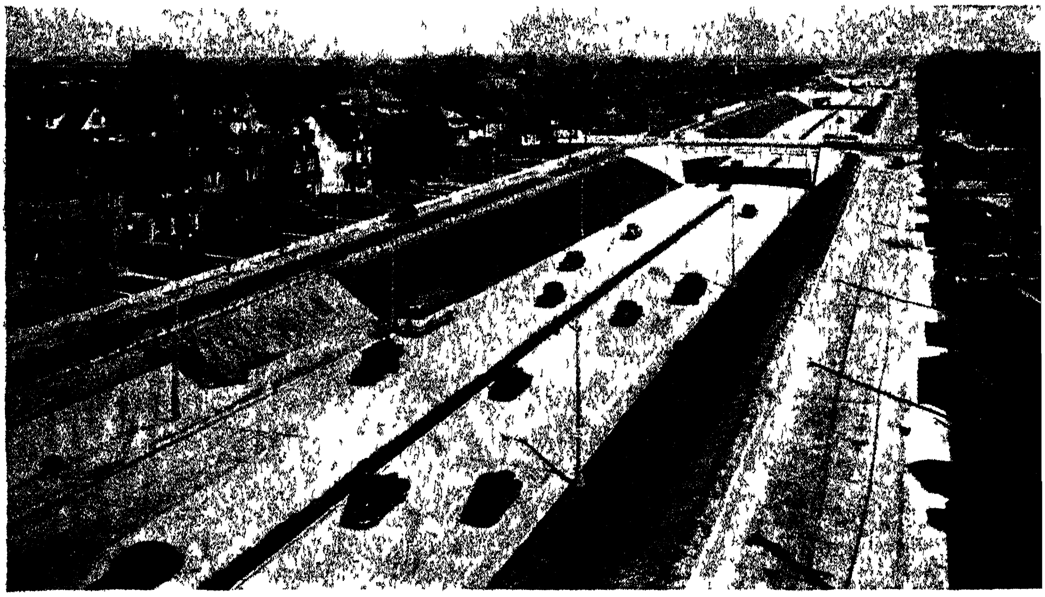
Pipe lines for petroleum and its products are independent of the weather, except that some warming of crude oil may be desirable in winter to reduce the viscosity and maintain the rate of flow.

Courtesy Chicago, Burlington & Quincy Railroad

Clearing the tracks in the Kansas-Nebraska area following one of the great blizzards of January, 1949. Snow drifted to depths greater than the height of the engines.

Speed and cost. The form of transportation that will be used for a given trip usually depends upon the speed or cost of the available types. Passenger and mail traffic is usually more concerned with speed than is freight, while most freight seeks the carrier with the lowest cost. Roughly, we can say that waterways are the cheapest and slowest form of modern transport, while airways are the fastest and most expensive. Highways and railways are intermediate on both scores.

A ship expends no energy in supporting itself and requires only moderate power for propulsion of a container of great bulk. For bulk goods, where there are adequate waterways, ships and barges carry large amounts of freight. For transocean freight, ships have virtually no competition from other forms of transport, and tramp steamers traveling at a rate of 10 to 12 miles per hour handle the bulk of such freight. Transocean passenger traffic too had no competition until the recent development of air transport. Fast passenger ships, traveling about 25 to 30 miles per hour, still carry large numbers of passengers. Canals, formerly served by animal-drawn barges at 2 to 4 miles per hour, are now being used more and more by motor vessels.



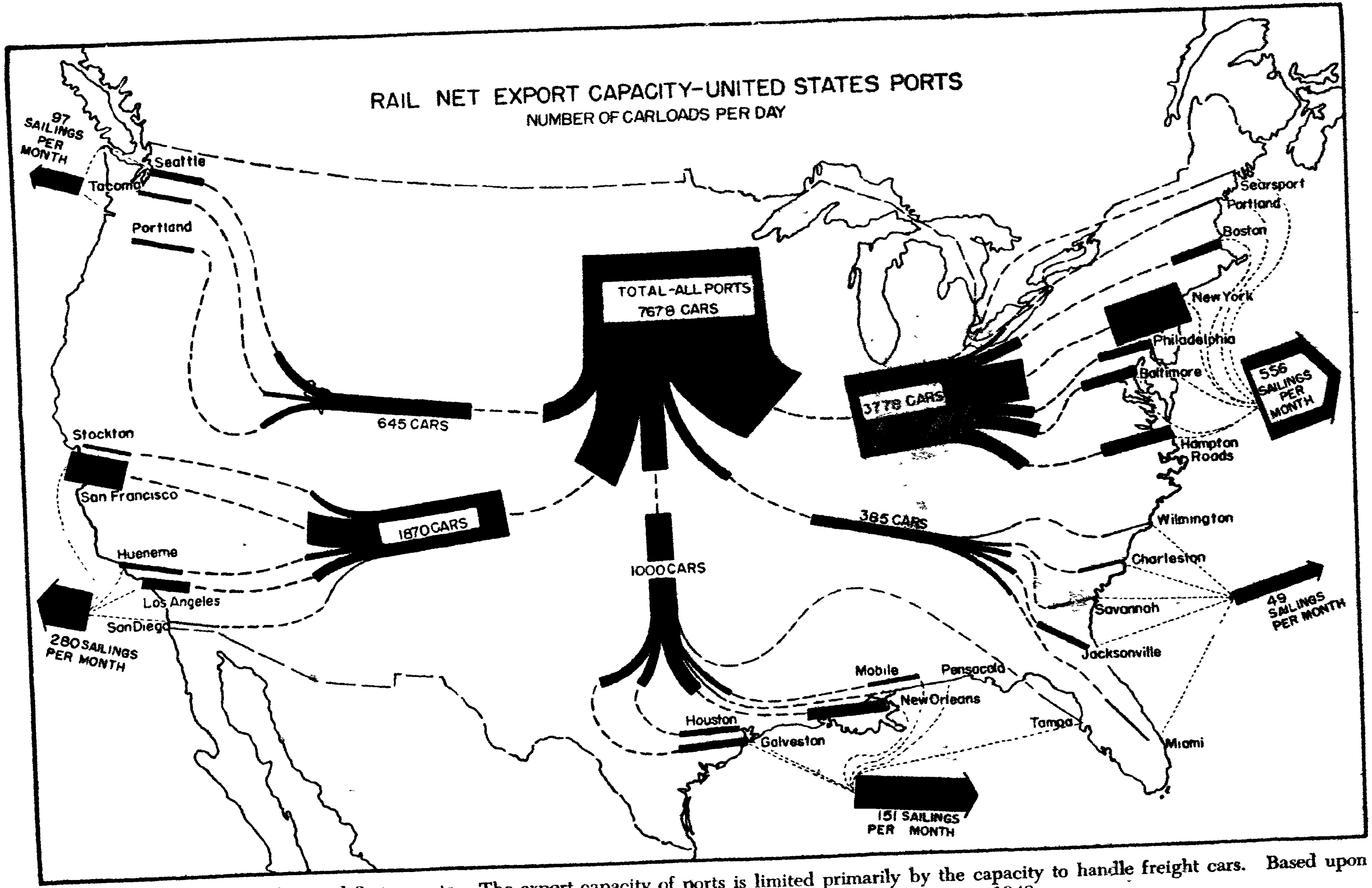
Courtesy Public Roads Administration

Davison Expressway through Detroit, Michigan Which is more frustrating, to drive on ordinary streets through a crowded city when you are in a hurry, or to cross a busy highway on foot?

Pipe lines are similar to waterways in cheapness and can transport their special type of freight at about half the cost of tank cars.

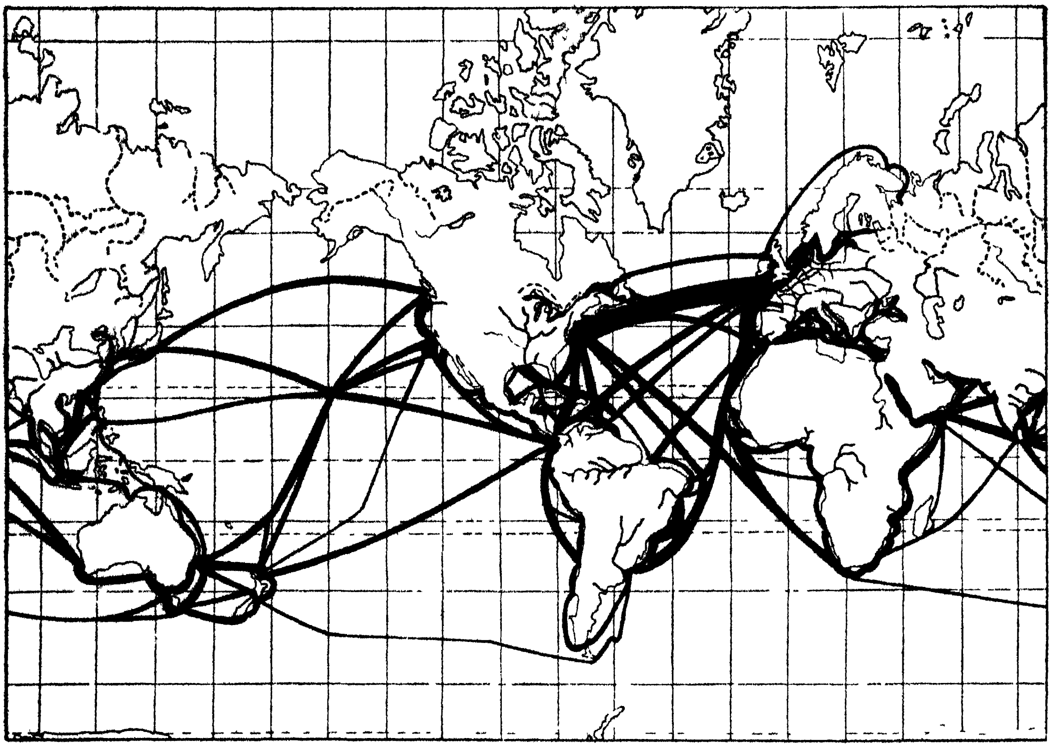
Railways normally transport passengers at speeds of about 40 to 60 miles per hour and ordinary freight about 15 miles per hour. Automobiles travel at speeds much like those of trains, but roads commonly are more winding than railroad tracks between two points, and if the points are far apart the train may have an advantage in speed. With its slowness in starting and stopping and its relatively restricted network of tracks, the railroads find their greatest advantage in hauling bulky freight over long distances. Trucks have cut into rail traffic sharply for short hauls, as busses and private automobiles have taken over a big proportion of short-haul passenger traffic. The greatest competitive advantage of the truck lies in its ability to pick up loads at the door of the sender and deliver them direct to the door of the buyer. The construction of highway express routes through or around cities is one way of speeding up automobile traffic (see Illus. above).

Airplanes on regular commercial airlines travel about 150 to 300 miles per hour, and for long trips are incomparably faster than any other form of transport. For flights of only 100 to 200 miles, the time consumed in going by automobile to and from the airports (usually on the outskirts of the cities)



Net daily export capacity of United States ports. The export capacity of ports is limited primarily by the capacity to handle freight cars. Based upon map from Office of Defense Transportation: Civilian War Transport, 1948.

is almost equal to that of the flight. The fare per mile is a little higher for planes than for trains, but the difference has not been sufficient to prevent planes from cutting into the long-distance passenger traffic and stimulating the railroads to offer more attractive accommodations to attract passengers. It is not economically feasible to carry ordinary freight by air. It was estimated that the cost of carrying freight by airlift from Frankfort to Berlin in 1948 was $100 per ton.



Ocean trade routes and inland waterways Width of lines is roughly proportional to volume of ocean traffic. Dash lines indicate inland waterways closed by ice seasonally.

Thus, each form of transportation has its special qualities that enable it not only to compete with but also to complement the other forms. In a well-balanced transportation system, each type would be available in the areas and for the purposes to which it is best adapted and with adequate connections with other forms of transport. The speed with which ocean shipments travel from source to ultimate destination is in most parts of the world not so much dependent upon the speed of the vessel as upon the speed with which railroads can deliver the freight to the vessel and can remove the freight at the other end after it has been unloaded at the port (see Illus. p. 529). In the present run-down condition of transport facilities in many parts of the world, resulting from wartime neglect as well as from actual war damage, freight sometimes lies on the open wharf for months before it can be hauled away to the interior. In transportation, as in production of raw materials and manufactures, there is a great need for capital improvement throughout the world involving a long, patient period of construction.

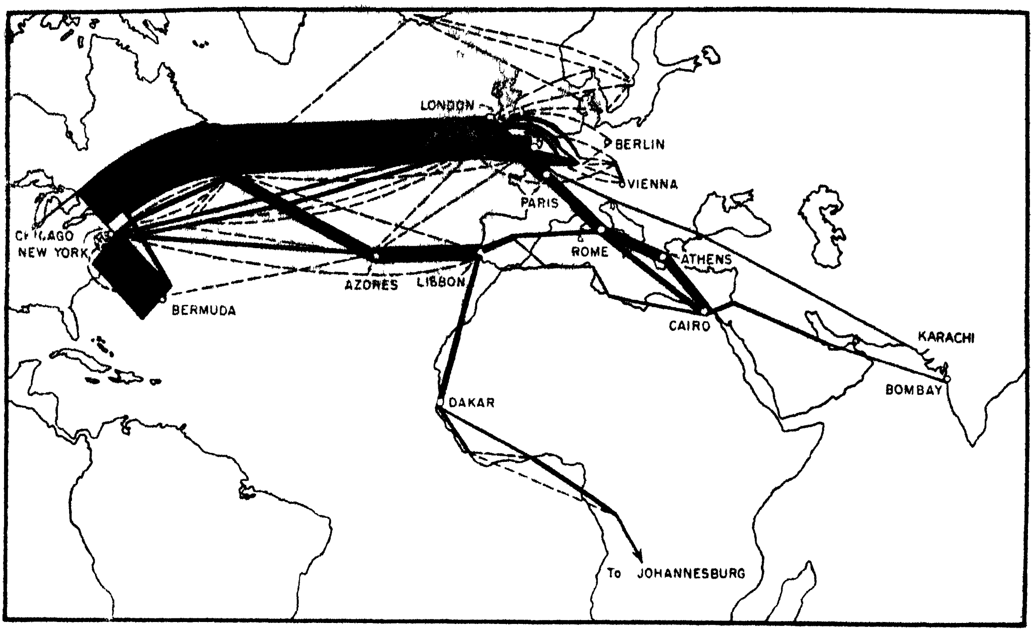
Transportation Routes and Patterns of the World

The present-day distribution of transportation systems is the result of the interaction of many factors including those outlined above. More weighty than any other factor, however, is the factor of need. Where people have concentrated in greatest numbers to develop their resources of agriculture, minerals, forests, and good location, there are the sources and destinations of the great trunk lines of transportation. If the people have developed along the lines of regional specialization, as in "western" civilization, the transport lines are strong. If the people are living in a self-sufficient culture, as in China, the transportation lines are weak, no matter how dense the population. Unconsumed surpluses are the basis of trade.

The world's transportation routes and patterns fall into two broad geographic groups: ocean transportation and inland transportation.

Ocean trunk routes. A glance at page 530, the map of ocean trading routes, leaves no doubt as to where the major route is located. It is the North Atlantic route connecting the northeastern United States with northwestern Europe. Most of our European Recovery shipments are merely following this trunk line that has existed for generations, in war and peace.

Why is there so much commerce along this line? The answer is given in part on the world population map, page 16, which shows the termini of the route as lying in two of the most densely settled areas of the world. These areas have developed an economy of the interdependent type, specializing in manufactures that they can exchange with the rest of the world for food and raw materials. Back of the New York end of the line, furthermore, lies not only a manufacturing area but also rich farming areas of surplus food. Wheat, corn, automobiles, and countless other products pour out from the heart of America by rail, lake, and canal through our northeastern ports more than from any other exit of the country (see Illus. p. 530). One-ninth of the exports of the entire United States flow through the port of New York alone.



International air traffic on American airlines, Atlantic area. Width of lines is proportional to number of passengers carried in March, 1947. Based on map by Civil Aeronautics Board.

Across the Atlantic to Liverpool, London, Cherbourg, Antwerp, Rotterdam, Hamburg, and a host of lesser ports, these products flow for distribution by rail, river, and canal to the European consumers. In return comes a flow of goods that makes New York the doorway for nearly one-quarter of the imports of the United States.

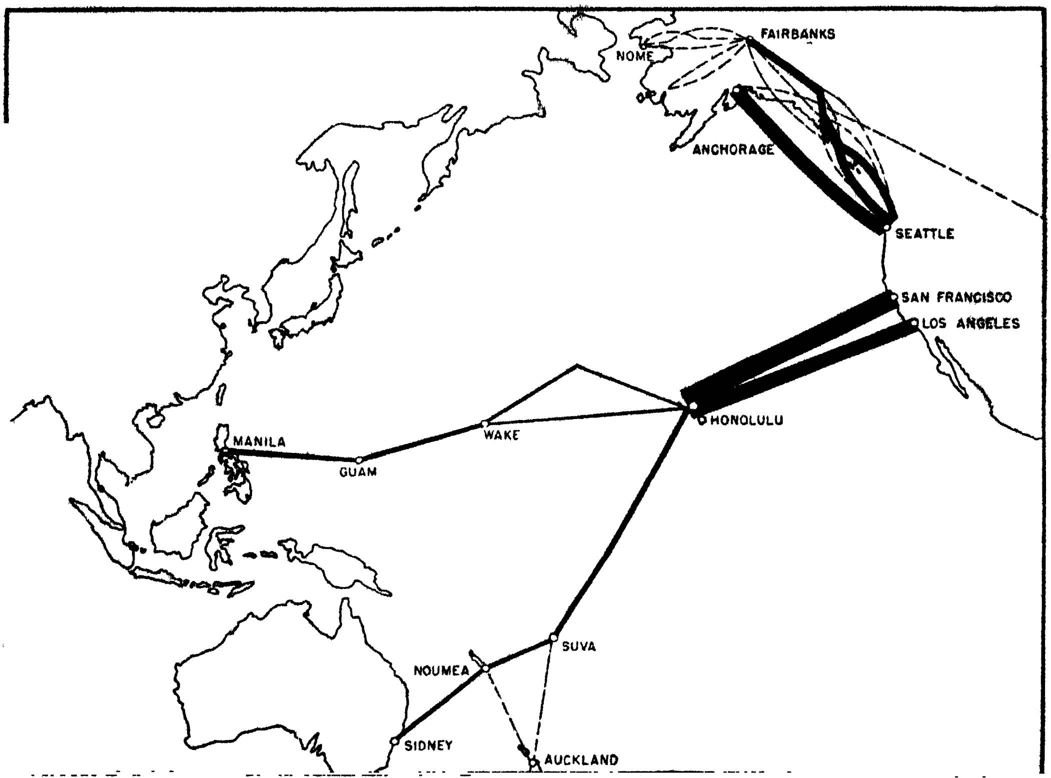
A second trunk line runs southward from northwestern Europe to Brazil, Uruguay, and Argentina, siphoning wheat, meat, wool, mutton, and coffee from the southeast coast of South America into the hungry mouths and mills of industrial Europe, and sending manufactures in exchange.

A third trunk line swings down the west coast of Africa to Capetown from Europe, drawing from South Africa and from connecting branches along the African coast more food and raw materials.

A fourth, the most ancient of the great historic trading routes, starts in northwestern Europe, runs south along the Spanish coast, then heads east through the Strait of Gibraltar. Through the entire Mediterranean and out the far end through the Suez Canal, this artery continues strongly to India. At India it branches, one line forming Australia's main link to the British Empire, and the other running east to Singapore, the great trading nucleus at the southeastern tip of Asia, and on to China and Japan. This is the rubber, tin, tea, teak, spice, and silk line to Europe.

From Japan, the trans-Pacific routes run eastward, one branch direct to Washington and California and one to Hawaii. Hawaii itself is the commercial center of the Pacific, with important routes radiating to the United States, Panama, Australia, and New Zealand, as well as to the Orient.

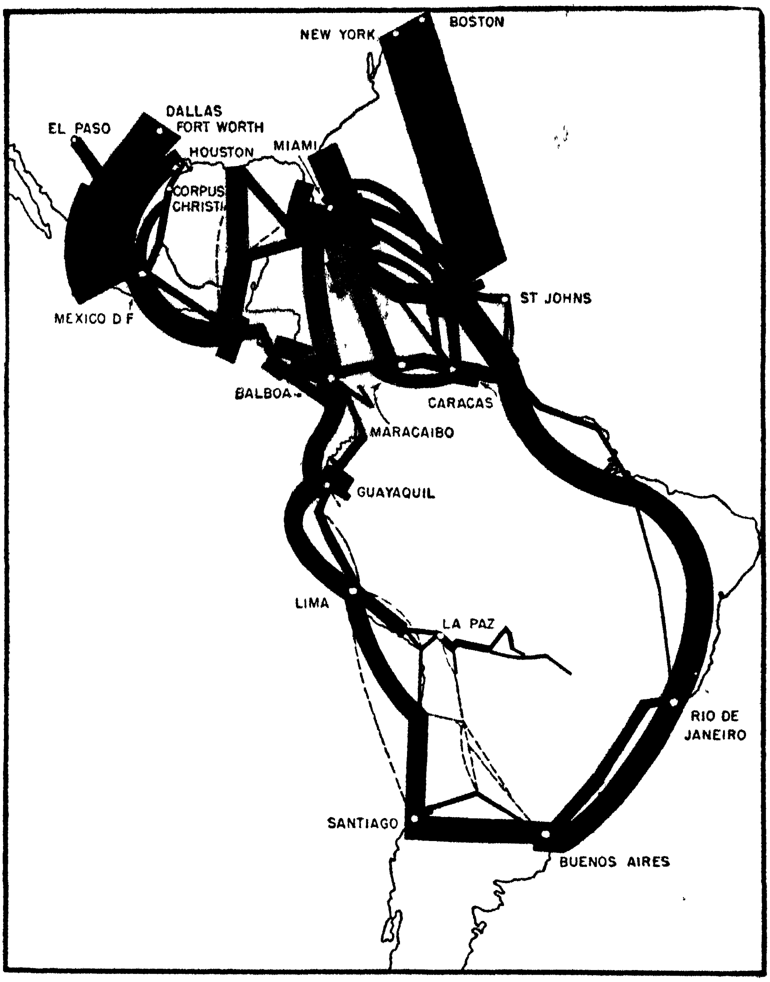
A sixth important route connects the At-



Air traffic on American airlines, Pacific area.

lantic ports of northeastern United States with Latin America (see Illus. p. 530). One branch heads direct for the Panama Canal, beyond which it taps the west coast of South America and handles intercoastal trade with California. Another branch goes through the Florida Straits to New Orleans, Galveston, and Mexico. Still another branch heads for Puerto Rico and the Venezuela oil fields, while a fourth joins the Brazil-Argentine line.

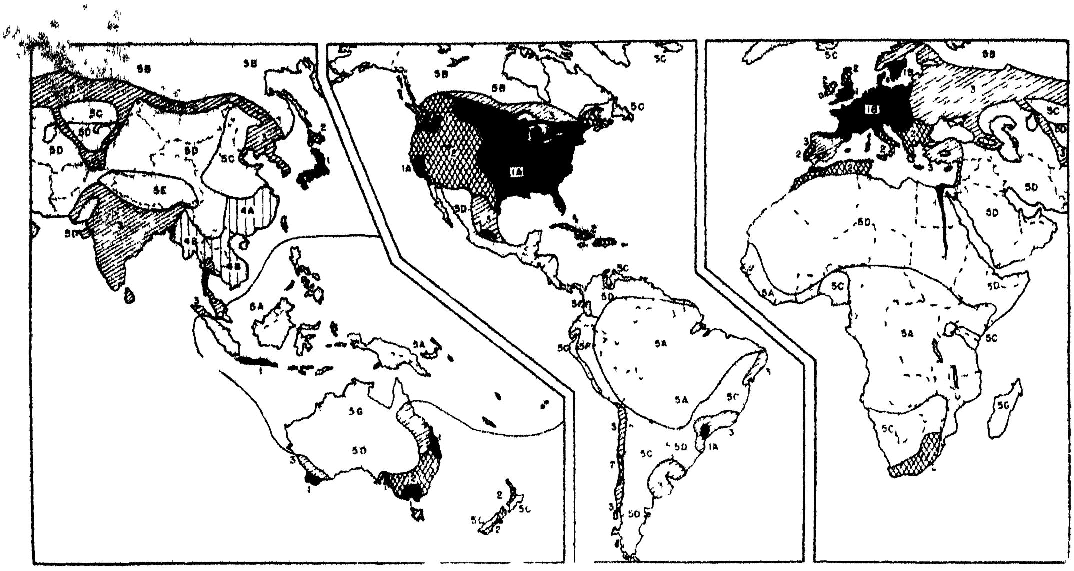
The trunk lines and smaller lines are guided in general by their targets of freight-producing lands. In detail, they are guided by (1) vital straits and canals, the bottlenecks of the world trade routes; (2) the nearest good ports to the sought areas; and (3) the great circle, or shortest-distance paths across the larger expanses of water.



International air traffic on American airlines, Western hemisphere.

Ocean airlines. Air routes follow the same general magnets as do steamships: the areas where products for world trade are to be found. Passengers rather than freight are the principal cargoes. The airline maps in this chapter based upon the volume of traffic of United States airlines with foreign countries, show the main outlines of the world airways system. The number one route is again the North Atlantic route, following the great circle from northeastern United States to northwestern Europe, with Newfoundland and Ireland as take-off points instead of New York and Liverpool or London. (See map, p. 531.)

The other air routes corresponding to the oceanic lines also are recognizable. The actual paths of the air routes show certain characteristic differences from those of the ship routes. In the first place, the routes are not confined to sea lanes: they can cut directly across land or sea, limited only by the willingness of the underlying countries to grant passage. In the second place, airplanes can ignore the straits and canals through which the ships must wind. Instead, the planes seek out the airports nearest to the desired great-circle routes. Flat land becomes more important than good harbors. Small islands, like the Azores and the series of Pacific islets, become of strategic importance—as "stepping stones" they replace corridors in significance. In India,



Principal forms of transport.

1. Mechanized, integrated, dense network
    - A. Railroads and all-weather motor roads
    - B. Railroads, all-weather motor roads, and inland waterways
2. Mechanized, integrated, sparse network
3. Railroads, few all-weather motor roads
4. Oriental
    - A. Canal boats, foot, few railroads
    - B. River boats, water buffalo, elephant
5. Primitive

    Vehicles
    - A. Natural waterways (power boats on main streams, canoes elsewhere) and foot (human)
    - B. Dog sled, reindeer sled, waterways (power vessels on some main streams seasonally, canoes on others)
    - C. Horse, mule, or ox wagon, few railroads

    Packing
    - D. Camel, horse, mule, or donkey
    - E. Yak
    - F. Llama, mule
    - G. Foot (human)

the chief concentration point of the east-west trunk line is Karachi, the capital of Pakistan, in the north: one of the great world wasp-waists of aviation. The corresponding bottleneck of the ocean routes is Colombo, the southernmost port of Ceylon, near which the ships from Suez must pass enroute to northeastern India, the Far East, or Australia. New York and Hawaii are as important for planes as for ships. Miami Mexico City, Kingston, and San Juan become the air centers of the Caribbean area.

Inland transportation routes and patterns. To some extent the inland systems of transportation are extensions of the ocean routes, but there is actually a greater amount of internal commerce carried on within the continents than external commerce between continents. The emphasis upon different types of transport differs widely from area to area in the world; relatively few areas have a reasonably complete and well-integrated system of modern transportation. The map on page 534 shows the approximate world distribution of transportation patterns.

North America. The United States has a diversified integrated transportation system with far greater mileage of railways, highways, airlines, and pipe lines than any other country in the world. The outstanding transportation route of the country is the one running from the ends of Lake Michigan and Lake Superior to the North Atlantic seacoast. It is not commonly realized that Duluth-Superior ships out a greater tonnage of freight than any other port in the United States and is exceeded in total trade only by New York City. The Great Lakes is incomparably the most important inland waterway of the country, shipping especially iron ore and grain eastward and coal westward. The waterway is extended to the sea by way of the New York Barge Canal and the St. Lawrence River. Roughly parallel with this line is the main trunk rail line of the country, from Chicago to the east coast, with branches to ports from Baltimore to Boston. The Atlantic ports of the northeastern network have about one-half of the nation's export capacity (see Illus. p. 529), and actually handled more than half of our exports during World War II.

A second major artery is the Fall Line route, a line of intensive rail transportation from Boston southward through New York, Philadelphia, Baltimore, Washington, D. C., and on to Atlanta. These two routes have the greatest volume of air traffic as well as ground traffic. The north-south air traffic continues dense all the way to Miami, Florida.

Other important routes, all of which are based primarily upon railways, are the Chicago to Gulf route, the Chicago to Atlanta route, the Chicago to Texas route, the southern, central, and northern transcontinental routes, and the Pacific route running through California, Oregon, and Washington. All the great railway routes are closely paralleled by through highways and airlines, for all of them serve the same traffic-generating areas.

Pipe lines have their own pattern of distribution, running primarily from the Texas, Oklahoma, and Louisiana oil fields to the northeastern industrial region, carrying crude petroleum to refineries, natural gas to cities and industries, and to some extent refined products to market (see Illus. pp. 382 and 392).

Between the dense, integrated transportation system of the eastern United States and that of the Pacific Coast, is the arid and semiarid region of sparse transport network. This merges northward into the north woods and tundra of Canada, with pioneer transportation, and southward into Mexico, where animal transportation still prevails over large areas, with a dense, integrated network only locally near Mexico City.

Europe. Northwestern Europe is distinguished by its dense, integrated network in which all modern forms of transportation except pipe lines play an important part. Unlike the United States, this area has a closely developed system of inland waterways, using the numerous gentle rivers and connecting canals. The map on page 530 shows the distribution of the world's principal inland waterways and gives an idea of the relative density of the network of northwestern and central Europe. The main European transportation route follows the great line of coal fields and industrial cities running from England through northern France, Belgium, Germany, Poland, and on into the Ukraine of the Soviet Union.

The Orient. Southeastern Asia has an old, primitive system of transportation, characterized by widespread use of human power to carry and haul freight and by an abundance of canals and coastal waterways to handle local traffic. Only limited areas —Japan, Java, Manchuria, and to a less extent India—have developed fairly dense networks of railroads and roads.

The Soviet Union. The Soviet Union has for many years depended primarily upon its railroads to handle its transportation, though its great rivers are of considerable importance. The main rail and water lines are now quite well established, but the process of extending them and adding new rail and canal links is continuing. In the first two years after World War II, the Soviet Union built about 600 miles of new railroads The system of paved highways is far from adequate, partly owing to sparseness of settlement and scarcity of hard rock; often the common dirt roads are converted into morasses in spring and fall. Winter is the best time for travel over much of the surface, through the use of sleighs.

The dry lands from Sahara to Mongolia. The dry areas shown on the Climatic Map of the World, from North Africa through Arabia into the heart of Asia, have only local and scattered development of modern forms of transportation, as along the Nile Valley, the Barbary Coast, and Palestine. Chief reliance for most of the area still is upon animal power: camels, horses, and donkeys in the low hot deserts, yaks in the mountainous areas of Central Asia. (See map, p. 534.)

Latin America, Australia, the Pacific islands, and the rest of Africa. These areas still rely largely upon simple forms of transportation for most of their traffic. Modern forms of transportation have developed dense networks chiefly in areas of local advantage near the coasts, as in the Pampas of Argentina, the Brazilian coast, central Chile, the Union of South Africa, the southern ends of Australia, New Zealand, and the lowland near Manila. Desert, tropical, or mountain lands of limited development prevail over much of the interior, and transportation is largely by foot, animal, or river boat (see Illus. p. 534). For many of these areas airways have proved extremely important in maintaining fast trade contacts with the rest of the world. Where the cost of constructing railroads or modern highways would be prohibitive, as in parts of the Andes, preparation for travel by airplanes can be made with only the expense of making a few airfields.

Polar regions. The Arctic peoples, too, use primitive canoe or animal transportation. Leather or rawhide canoes are widespread in northern Siberia and North America, reaching a peak of perfection in the Eskimo kayak. Reindeer are used throughout the far north of Europe and Asia as draft, pack, and saddle animals, and dog sledges are the standard land vehicles in northern North America and parts of Siberia. "Moss" for reindeer and meat for dogs constitute commonly available sources of energy. Most parts of the Arctic are too sparsely settled and have too meager an economic base to support mechanized ground transportation in the adverse northern environment. Airplanes, however, needing only a smooth lake or level field for landing, have come to play an important part in the life of Arctic lands.

Telecommunications. From the viewpoint of economic geography, telegraph, telephone, cable, and radio systems are significant chiefly as means of facilitating commerce. They do not themselves move freight or passengers, nor do they form a conspicuous portion of the physical landscape. It is of considerable significance that radio communication, like airplane transportation, can be installed in a given area with relatively little expense, providing instantaneous contact with the outside world. In the past, the establishment of telecommunications required the slow and expensive process of stringing wires between communicating areas.

The earlier forms of telecommunication, and the still slower system of mail, have of course maintained and increased their value for most two-way communication. Air mail traffic, in particular, has increased phenomenally. All forms of communication and transportation play their part in developing the economic geography of the world as an interdependent system of productive regions of diversified specialization.

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Chapter Thirty

THE CHANGING WORLD

WHY DO SUCH CONSPICUOUS AREAS OF density and of sparseness exist as are shown on maps of world population? In the first two chapters of this book we not only raised questions as to the causes of this uneven distribution, but also as to the consequences, particularly those of economic significance. Through the chapters that followed we attempted to hold rather closely to the four queries suggested at the outset—(1) where, (2) what, (3) why, and (4) what of it? While we cannot now attempt to summarize all that has been presented in the foregoing chapters, it may be well for us to recall some of the most salient phases of the causes and consequences attending the distribution of the more than two billion people who possess this earth. Broadly speaking, the distribution of population is directly related to environmental factors, although, in the details of distribution, nongeographic factors often play important roles as well.

Uneven distribution of natural resources. Fundamentally, population must adjust itself to the means available for making a living. In the preindustrial ages agricultural land was the principal natural resource which governed density of population. Even now, the most densely populated large areas are found where man depends almost entirely upon local agricultural production. This is notably the case in India and China, where 75 to 80 per cent of the people live on farms. Fertile cultivable lands with a favorable climate must stil be ranked as the world's great populatio breeders. Now, as in ages past, such land not only produce the materials necessary fo human existence, but also give rise to surplus population. The lands capable o such productivity are limited and unevenl distributed over the earth. Other land have lower potentialities and hence canno support large numbers. Cultivable land are the rich grain lands, and there peopl may become numerous; noncultivable land at best are but pasture lands and are thu foreordained to sparseness.

With the development of mechanized industry, however, the basic resources used b man have been extended beyond those o the agricultural lands to the realms of minerals and power. Moreover, industrial development has made it possible for me equipped with machines to produce larg surpluses of agricultural goods and thu to release workers for mines and factories In the United States, for example, accordin to the census of 1945, only 19 per cent o the total population were classified as rural and it is highly probable that 10 to 15 pe cent could supply the entire needs of th nation for agricultural products. The hig development of industry in western Europ would not have been possible without th surplus produced by machine agricultur in the United States, Canada, Argentina and Australia.

Industrialization, particularly in easter

North America and northwestern Europe, has given rise to areas of congested population where the production of factory goods constitutes the principal economic activity. This activity utilizes mineral and power resources rather than agricultural lands, although the demand for food induced by the dense industrial population leads to intensive production of agricultural commodities as well, particularly of such vegetables and dairy products as cannot readily be shipped long distances. Thus, natural wealth of minerals, power fuels, and water power serve to induce areas of heavy industrial population. These natural resources, like the productive agricultural lands, are also distributed very unevenly over the earth.

Uneven distribution and diversity of production. Productivity is dependent, however, upon the human resources as well as upon those of the plant and mineral worlds. Man is a factor as necessary as soil or coal and iron ore. Primitive man depends directly upon the resources of his immediate environment. He is enabled to live in a given locality if wild life—plant and animal—is found in sufficient quantity for his subsistence. The skills needed are those of selecting nourishing plant products, avoiding the poisonous ones, and of capturing game and fish. The problems of living are simple and the diet is monotonous. This is an extreme example of local self-sufficiency. In that state of society man has not acquired the mechanical skill necessary to harness sources of energy outside of himself, and he has not learned how to co-operate in the exchange of surpluses with others who live at remote distances.

As man advances in the scale of civilization, he increases the efficiency of his methods of production of goods to satisfy his material needs. No longer is all his time devoted to the hunt and chase or to crude tilling of the soil for the sake of meeting his elemental needs of food, clothing, and shelter. He learns how to harness other sources of energy and to use other forms of power than his own. Such development has been in progress during all the ages past. Animals were trained to carry burdens and to pull loads; winds and streams were early utilized by means of crude windmills and waterwheels; and later the energy of coal, petroleum, and natural gas was made available as power through the mediums of gas and steam engines and electric motors. These can now be utilized efficiently to do work on a grander scale and at a much lower cost than would be possible if only the labor of men and animals were available. In the industrially progressive nations, man is engaged mostly in directing the energy whereby the work of production is accomplished, and his own muscular power plays but a minor role. Because of the enormous amount of energy he now has at his command, his capacity to produce goods and to transport them has surpassed the most optimistic dreams of a century ago.

However, even modern man and his machines are limited in their activities by the environment in which they operate. That they can "conquer nature" to a degree beyond that possible in the premachine eras is true, but the economic limits are quite closely drawn. Man *can* produce bananas in the middle latitudes, but only at enormous cost compared with their production in the tropics. Excellent table grapes are produced in England, but the cost is many times as great as in the Mediterranean lands, where they are grown under favorable climatic conditions. Man could build as good railway locomotives in Florida as in Pennsylvania, but the cost would be much higher because of the necessity of transporting the raw materials from distant sources. Therefore, it is clear that, even with the great technological advance which marks the modern industrial world, economic production depends upon the fundamental factors of soil, climate, power resources, raw materials, and available markets. These factors have different relative weights in the various sections of the world, but none can be ignored if efficient production is to be attained.

Under modern conditions the production of many agricultural and industrial commodities tends to be highly specialized. Certain areas may have optimum natural conditions for the output of only a few products, while other commodities can be produced more efficiently elsewhere. If men desire to have the benefit of many commodities, they must arrange to exchange their local surpluses for goods produced elsewhere. The local self-sufficiency of pre-industrial days is not now possible within sound economic limits; high standards of living are inseparably linked with exchange of products. The physical facilities for such exchange have been developed in remarkable degree. Steamships span the seven seas and connect the continents speedily and efficiently; railroads and improved highways facilitate swift overland transport; canals and rivers carry bulky and slow-moving cargoes at low cost; air navigation can now reach all parts of the earth at amazing speed and with little hazard. Communication by mail, wire, cable, and radio binds the world together so closely that the most distant points can hold converse upon a few minutes notice. As far as production, exchange of goods, and communications are concerned, the stage is set for progress at a rate which staggers the imagination. In the face of all this we experience troubled economic times even where high production is attained. Why? The oft-repeated answers of overproduction, too much mechanization, economic maladjustment, and so on, are unconvincing. The solution of the problems of continued progress and improved standards of living for the masses demands the attention of thinking people everywhere.

Since people who live within the realms of advanced industrialism are the beneficiaries of controlled power, efficient production, and means of transportation and communication, they should face new problems by looking forward not backward. They should not be tempted to return to manual methods in lieu of machines with which to do needed tasks, even though some of the economic problems of modern society have not been solved. Production, both in kind and quantity, necessarily varies with geographic conditions. High standards of living, however, depend not only upon production, but also upon a ready exchange of products, that is, upon trade.

Trade as an index of civilization. We believe it fair to assert that the term *civilization* implies recognition of the rights of other people or persons as well as insistence upon one's own rights; that it implies a state of mind as well as a state of material and cultural achievement. Neither an individual nor a nation deserves to be called civilized if it willfully ignores or overrides the rights of others and is unwilling to trust controversial issues to the verdict of neutral, fair-minded judges. Such breaches of conduct are nearly always causes of war or are associated with it, and readiness to resort to war surely cannot be considered an index of civilization. Disregard for the rights of others is not, however, limited to war conditions; too often it occurs in times of peace as well, and most blatantly so in the realms of trade.

Since it cannot be denied that trade tends to promote high standards of living, is it not fair to hold that honest promotion of trade is a sacred duty and should be regarded as such? Is not the trade obstructionist an enemy of progress? Because of the distribution of natural resources, the various regions of the earth can each produce some commodities advantageously, others with difficulty, and still others not at all. Pennsylvania and West Virginia, for example, can produce cereals and meats, but not so efficiently as can Iowa and Kansas, whereas they can produce heavy manufactures of iron and steel more efficiently. Will anyone deny that a ready flow of trade between the former and the latter named states is sound business practice? Similarly, the exchange of the fruits of Florida and California for the manufactured goods of New England and the cereals of the Mississippi Valley meets general approval. One wonders, however, what might have been the result if the territory which is now the United States had been occupied by a number of small countries, as is the case in Europe. That the builders of the Constitution recognized the significance of this problem is clearly shown by their action in preserving for the national government alone the right to levy import duties. In this manner economic restrictions upon the ready flow of interstate trade were effectively prevented.

The United States, because of its vast size and widely varied resources, is about as nearly self-sufficient as any nation on earth. Nevertheless, the highest welfare of our citizens demands the encouragement of foreign trade. Some commodities, such as coffee, tin, and nickel, must be purchased abroad because we cannot produce them from our own resources, while others, as tea and sugar, can be produced elsewhere at so much lower cost that to attempt to supply our entire needs would be highly uneconomic in practice. During much of the nineteenth century this country was dominantly agrarian, producing large surpluses of grain, meat, and cotton to be sold abroad to pay for needed imports and interest on moneys borrowed by citizens for the equipment of expanding industries and railroads. Now, however, capacity for industrial expansion has been increased so that surpluses are available for foreign markets; but they can be purchased only if payments can be met by the equivalent goods or services sold for use in this country. Thus, for our domestic prosperity, a ready flow of imports as well as of exports is a necessity.

Economic nationalism in relation to economic progress. After World War I economic nationalism developed with increasing vigor. The war was responsible for disrupting the economic machinery which had begun to function quite smoothly during the preceding period of peace. The nations at peace as well as those at war were obliged to forego the use of many imported materials which they had come to rely upon; hence, a psychology of fear was established which led to a widespread ambition for each country to produce all commodities possible without regard to economic feasibility. Within the United States the industrial expansion induced by the war demands had caused a factory development temporarily in excess of domestic needs. Through increased tariffs, industrialists hoped to protect the home markets against foreign competition, and yet not to relinquish their favorable position in the world markets. European countries, ordinarily our greatest foreign customers, not only found themselves impoverished by the destruction wrought in 1914-1918, but also found their markets in the United States curtailed by tariff walls of rapidly mounting height. Furthermore, their prewar trade with other nations had been seriously impaired and in many instances totally destroyed.

Postwar business was confronted by a hostile, suspicious world. Foreign trade was hampered not only by national suspicions, but also by lack of financial resources and lack of credit. Under the circumstances, nations began to rebuild on a basis of self-sufficiency. Italy, for example, entered upon a campaign to produce her own wheat rather than to buy it, even though she could obtain it more cheaply from Argentina and the United States. Germany took up the cry of self-sufficiency in breadstuffs and fats, although it is not a country well adapted for wheat raising, and normally should import great quantities of lard and other animal products. Similar movements were widespread among other nations of the world.

For a time the effects of these policies were not keenly felt because a decade was necessary in which to refill the gaps left by the wholesale destruction wrought during World War I. The United States particularly experienced a postwar prosperity for which a heavy price was paid, although it was not so understood at the time. The nation had a tremendous surplus-productive capacity in agriculture and industry, and it had accumulated huge wealth for which channels of investment were sought. Foreign markets were beckoning. The surplus production was sold abroad and paid for by loans of American money. Exports increased to huge proportions under such stimulus, and while imports also increased, Americans boasted of their large "favorable trade balances" reported yearly. The United States, which had become the world's greatest creditor nation through loans granted during and following the war, held with almost childish simplicity to the belief that foreign countries could pay their debts by continued borrowing of money and by buying more from us than they were selling to us.

That belief was, of course, one impossible of realization. After a time it dawned upon business that the profits of which it had boasted were being paid for by capital rather than by income from earnings. Foreign purchasers found it necessary to borrow still more money for the payment of interest on moneys already owed, and hence the balances available for new purchases became smaller. The speculative structure, domestic and foreign, which had been built upon the false basis above outlined, tottered, and, after a few warning tremors, crumbled in the great crash of 1929. It was a cruel but inevitable ending of an economic pipe dream.

During the 1930's the struggle for national economic self-sufficiency among the countries of the world continued with fury unabating. As trade declined, each nation tried to remedy the difficulty by making trade even more difficult. When duties alone seemed insufficient to reduce import trade, quotas were established, and in some cases absolute embargoes. With almost universal agreement that economic difficulties arise when distribution is impaired, the remedy advocated by many national leaders was *further impairment!* Following the 1930's, now often referred to as the decade of depression, came World War II with destruction of lives and wealth on a scale tremendously greater than was true of the war of 1914-1918. The same general economic pattern was set in motion, with war controls, wholesale destruction of goods, ensuing scarcity, rising prices, and unprecedented boom conditions following the cessation of the shooting war. Three years following the end of open hostilities found scarcities still dominant in many lines of durable goods and prices in such instances rising and inflation still in progress. The question "what next?" is as yet unanswered, but if the pattern of economic behavior continues to be followed the results may readily be forecast. If or when recession comes, whether it be slight or severe, the fundamental principles that call for increased efficiency of production and of exchange of commodities should be kept actively in the forefront. When economic adversities threaten, improvement rather than impairment of production and trade must be the watchword if constructive outcome is to be expected.

Business—a form of public trust. In our modern industrial civilization, the type of courageous integrity represented by the pioneer woodsman or plainsman of the advancing frontier must be replaced by similar courage and integrity in a setting much more difficult. Co-operation is necessary for the achievement of success in a complexly organized society. The pioneers along the new social and economic frontier must not only be men of undaunted courage, they must have the scientific spirit, they must ever search for truth and take their stand in line with facts in so far as it is possible to ascertain the facts. While recognizing the truth of the adage "Production is the basis of wealth," they must recognize that general and continued prosperity depends upon fair and widespread distribution of the benefits of production. Maladjustment of the machinery of distribution is as certain to produce want and suffering among innocent victims as is maladjustment of the machinery of production.

Whatever criticism may be made of the industrial progress attained, it cannot be denied that our ability to produce has been so enhanced that the fear of famine has been dispelled. Among modern nations the economy of scarcity has no place. No longer need there be fear of a world growing old, nor need there be fear of imminent overpopulation.

A change of major importance has come in the shift from rural to urban population. The farmer population, formerly three-fourths of the total, always retained its land, which carried with it a feeling of social security. Now we have a great industrial population, largely without direct property interests, and one whose whole future is tied up in terms of jobs. Under such conditions, social and economic security, vital to the people as individuals and to the life of the nation as well, must rest upon a firm foundation of justice to both labor and capital. The worker deserves full consideration as a human being, as a partner in the business game, and not merely as a cog in the machine. On the other hand, workers must realize that the machines which enable them to produce goods in abundance and at relatively low cost are the results of the labor of other workers. Capital is thus necessary for maintenance of efficiency, and must have equal consideration with labor in order to insure justice and wellbeing for all. The efficiency of production is such that in times of peace men need to work fewer hours than in the past and yet have all that they are prepared to enjoy. Such an industrial status is indeed a tribute to the efficiency of mechanical inventions in the utilization of available power resources.

What of the future? Is it not true that we are living in a world of rapid change? The productive genius of man has been ably demonstrated, and the necessity of the scientific spirit is clearly evident. The social genius is still to be tested. Man must study the world in which he lives. He must familiarize himself with his own environment and also with the environment in which others live. He must search for the facts as to the qualities, kinds, and distribution of the natural resources upon which production depends. He must learn to use wisely, with true ideals of conservation, the resources which are irreplaceable; these include the soil as well as fuel and other minerals. A scientific study of the best use of the land will help to avoid economic waste and its associated hardships. But even more is needed. Man must have courage to voice his convictions and to plan his actions in accord with facts. Intellectual honesty often requires the highest type of courage.

In the social and economic world which confronts us are problems which should fire adventurous minds with enthusiasm. There is need for the brightest and most daring minds to work unceasingly at the tasks of learning fuller truths about the material world in which we live. That, however, cannot be the final goal. Beyond lies the problem of developing greater and deeper human happiness as a reward for the increased productive efficiency. Men will have many hours daily wherein they need not toil at grinding tasks. Such hours will be theirs for the development of their higher needs. Those hours should be conducive to scholarship, to literary achievement, and to the fine arts of painting, drama, and music. May those hours become, in a true sense, ennobled leisure!

APPENDIX

Maps

AMONG THE EARLIEST WRITINGS KNOWN have been found pictorial charts designed to show locations of places described or discussed. Crude and simple though they be, they are illustrations of man's attempts at map making. Later, as explorations became more carefully recorded and locations more accurately established, higher grade maps were made. Interesting maps have been found among old Egyptian papyri and among Babylonian ruins. The Greeks and Romans left many maps which give us quite reliable pictures of the parts of the world known in their times.

The natives of Polynesia constructed maps of extensive areas out of palm leaves, showing islands in their respective locations by means of shells attached to the framework. The Eskimos of North America and the Yukaghirs of northeastern Asia made maps on birch bark.

The earth is most accurately represented by a globe. Such a miniature replica avoids distortion of the major earth features. Inasmuch as globes are bulky and not practical for use in books or atlases, the need for some means of representing the earth, or parts of it, on a plane surface is an imperative one. This need raises the important problem of how to represent the surface of a sphere or a portion of it on a flat surface without serious distortion of size or form. A sphere, or even part of a spherical surface, cannot be made into a flat surface without some distortion. This will become apparent if one attempts to flatten out even a small part of a deflated rubber toy balloon. It has therefore become necessary to devise methods whereby the earth's surface can be portrayed with as near approximation to the truth as possible.

All maps represent areas in more or less distorted form. The larger the part of the earth portrayed by the maps, the greater, of course, are the distortions. If only a very small part of the surface is portrayed—for example, an urban settlement or a township—the actual distortions are so small as to be negligible.

In making a map, geographers must contend with the mathematical difficulty of representing the curved surface of the earth, or any portion of it, on a plane surface. As a matter of fact, no map, however carefully it may be drawn, can at the same time represent accurately both form and size of an area. Since maps are made to serve specific needs, methods have been devised whereby faithful representation of the particular features desired is achieved, but this usually entails sacrifice of accuracy in other features. Thus, different map projections have been developed, each with specific advantages and disadvantages.

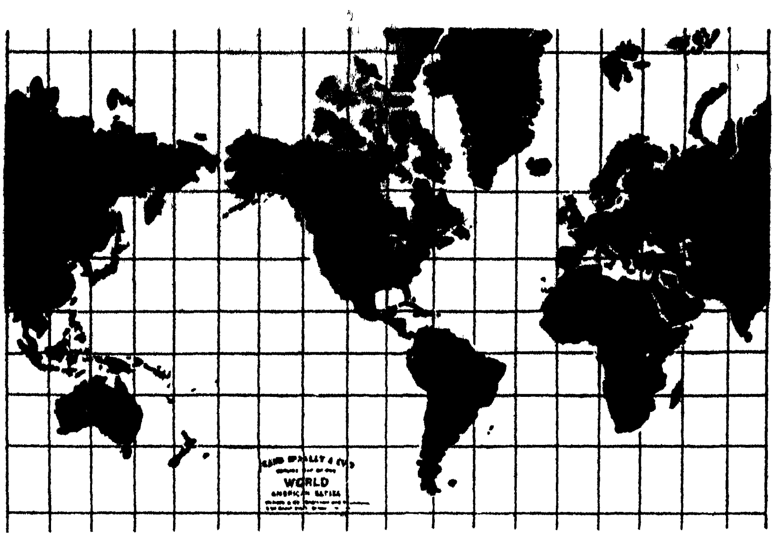
Meridians and Parallels

The migratory instinct of man, the advantages of trade with distant lands, and man's desire to explore and describe, early created a need for some method whereby it would be possible to state accurately the location of places. On a spherical surface the problem of location is a difficult one, since no fixed points are available. However, since the earth rotates on a permanent axis, the terminals of this axis, known as the *poles,* provide convenient fixed points for the creation of a network of lines with which it becomes possible to fix the location of any place on the surface of the globe. This network consists of two sets of lines intersecting at right angles. The *meridians* extend in north-south directions converging toward the poles and diverging toward the equator. The *parallels* extend east-west, and any two are of course equidistant throughout their extent. The *equator* is a great circle dividing the earth into northern and southern halves and therefore is the initial circle, latitude 0°, for reckoning distances north and south (see Illus. p. 16). As an initial meridian from which to reckon distances east and west, the meridian that passes over the well-known naval observatory at Greenwich (London) was chosen by international agreement, and therefore it has become recognized as the Prime Meridian, longitude 0°. From it others are reckoned eastward to longitude 180° E. and westward to longitude 180° W.

Mercator's projection. The *grid* of any map projection is obtained by projecting the parallels and meridians upon a flat surface tangent to the globe. For example, in Mercator's projection we may imagine a huge cylinder placed over the globe tangent at the equator, and the map projected from the center of the globe. In this projection all the meridians are drawn as straight north-south lines and the parallels as straight east-west lines. While on the globe the meridians all converge to common points at the poles, in Mercator's projection the distance between two meridians is the same at the poles as at the equator. To compensate for this distortion of distances between meridians, the parallels are drawn so that the distances between them increase correspondingly toward the poles (see Illus. above).

Since parallels and meridians are straight lines on Mercator's projection, distances are also. For this reason the navigator finds the projection convenient to establish his course. He needs only to draw a straight line from his location to his destination, measure the angle which this line makes with a parallel or meridian, and steer the course accordingly. Although such a course is not the shortest route, it has the advantage that the sailor can maintain the same bearings.

However satisfactorily Mercator's projection represents directions, it is poorly suited for representing areas of land masses, especially those located in the higher latitudes. On this projection Greenland appears as large as Africa, whereas it is really only about one-thirteenth as large. This excessive distortion is readily understood if one bears in mind that Mercator's projection makes the poles, which are really points, into lines as extensive as the equator, and that parallels are spaced farther and farther apart toward the higher latitudes in the same ratio that distances between meridians are exaggerated. On wall maps used for instructional purposes, the use of this projection should be discouraged.

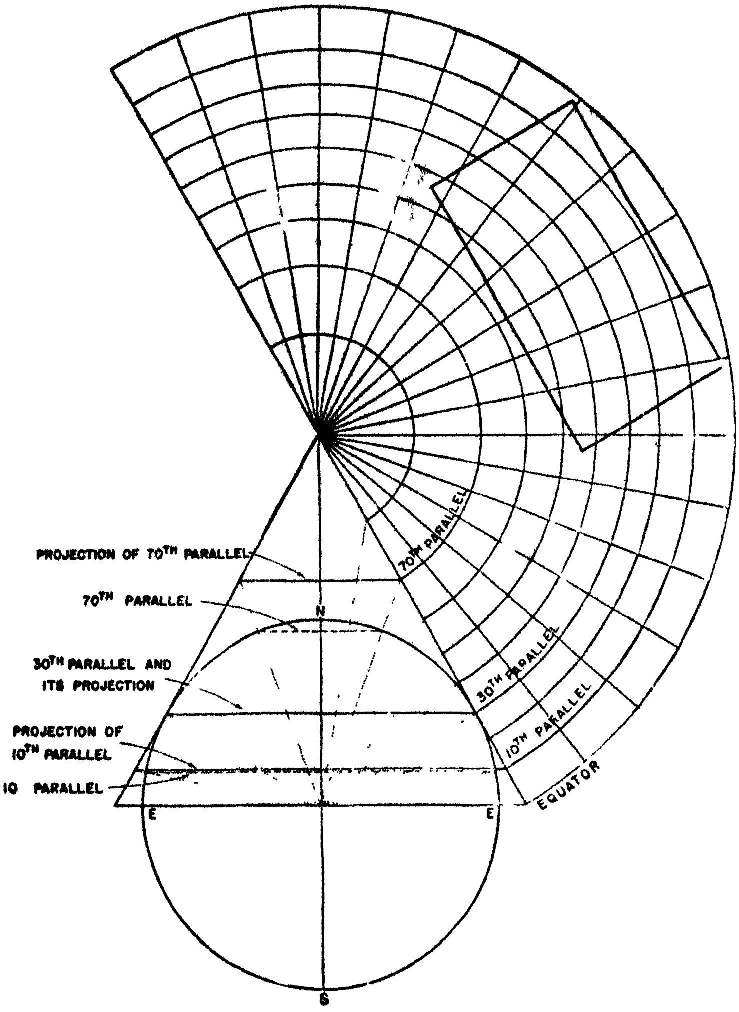


Prepared by I A Carlson

Mercator's projection of the world

The conic projection. The conic projection is far better suited to represent the land masses of the world than is Mercator's projection. In drawing the conic projection, use is made of the fact that part of a sphere is similar to part of a cone. If we can imagine a huge cone placed over the earth, and parallels and meridians drawn on it from the center of the globe, the resulting grid, when the cone is unrolled, would closely approximate the parallels and meridians on the globe itself within a belt not too far removed from the parallel of tangency. The meridians appear as straight lines radiating from the pole and the parallels are represented by concentric arcs about the pole as a center (see Illus. above).

The especial virtue of the conic projection is that small areas may be represented with relative fidelity. In the figure, the part of the cone nearest the parallel of 30° corresponds to the area of the globe. East-west distances along the parallel of tangency are represented accurately. An area mapped within a strip nearly tangent to the sphere will show little distortion in latitude. Distortion increases northward and southward from this strip. The flaring edge of the cone stretches the map in all directions, thus causing increasing distortion of form and area with increasing distance from


PROJECTION OF 70TH PARALLEL
70TH PARALLEL
30TH PARALLEL AND ITS PROJECTION
PROJECTION OF 10TH PARALLEL
10 PARALLEL
N
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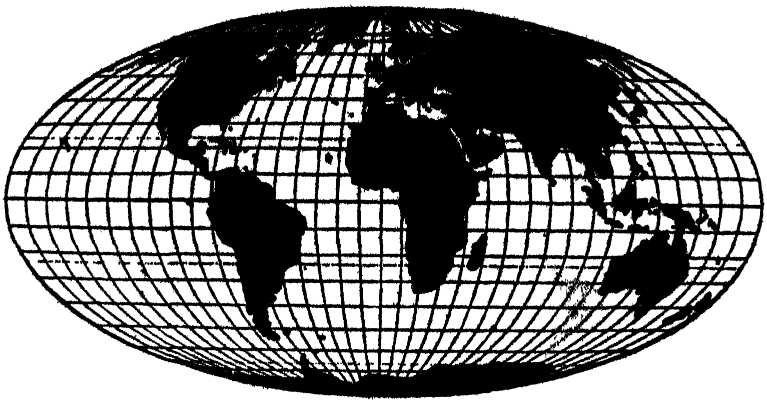
70TH PARALLEL
30TH PARALLEL
10TH PARALLEL
EQUATOR

Central conic projection The rectangle shows the type of map grid obtained by using this projection Especially suitable for small areas and for regions which have relatively large longitudinal extent.



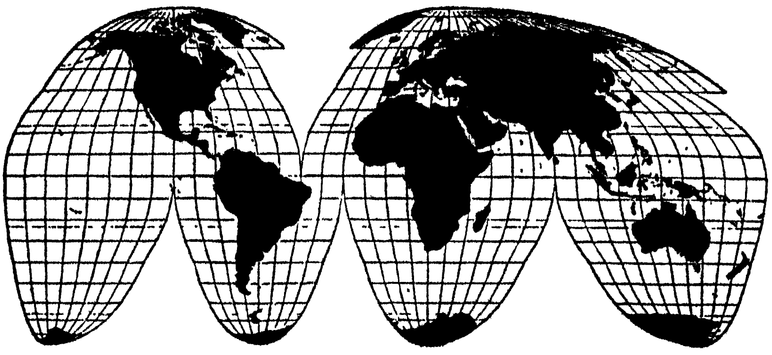
Prepared by F A Carlson.

(A.) Mollweide's homolographic projection of the world.

the parallel of tangency. Consequently, the conic projection is best suited to show areas that have considerable east-west extent. For this reason, it is often used in making maps of Europe, and particularly of the Mediterranean lands. Generally speaking, the conic projection is also well adapted to show small areas.

Polyconic projection. In the discussion of the conic projection it was stated that distortion increases northward and southward of the zone of tangency. To remedy this difficulty and make all of the sphere approximately tangent to the cone, the polyconic projection has been devised. Polyconic means "many cones." If, instead of a single cone placed tangent along some parallel on the globe, we picture a series of superimposed cones, each tangent at a different latitude, we can understand the idea of the polyconic projection. Since distances at each line of tangency are correctly represented, and the distortion near each such line is only slight, it is possible by this projection to construct a map of greater accuracy than on the simple conic projection. On the polyconic projection the meridians curve toward the poles and the parallels spread somewhat toward the margins, thus giving to the map an appearance of bulging. The polyconic is preferred for showing large areas, particularly those with great north-south extent, as, for example, Africa, North America, or South America.

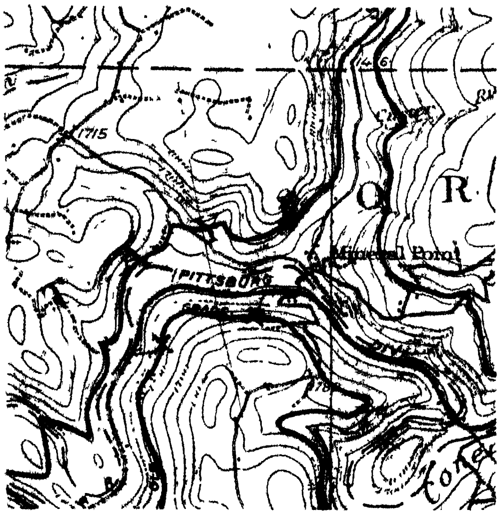
The Mollweide homolographic projection. None of the three projections named above is suitable for representation of the entire globe on one map. Homolographic projections get their name from the fact that they are equal area projections. On them any given quadrangle bounded by two parallels and two me-



(B) Goode's interrupted homolosine projection. Goode Series of base maps and graphs, by permission of University of Chicago Press.

ridians is equal in area to any other quadrangle similarly bounded. The Mollweide projection, named after its inventor, is extensively used because it avoids distortion of areas. It involves, however, distortion of directions, particularly near the borders of the map grid. This is in contrast to Mercator's projection, which does not distort direction but distorts areas (see Illus., p. 545).

On the Mollweide projection all parallels are drawn as straight lines. The mid-meridian is also drawn as a straight line, but the other meridians become more and more curved, particularly toward the poles. (See Illus. A, p. 547.)



Section of a topographic map

Goode's interrupted homolographic projection—the homolosine. The homolosine is a modification of the Mollweide projection. The late Professor J. Paul Goode conceived the idea of centering the larger continents on meridians which may reach from pole to pole or merely from pole to equator. The spacial interruptions which occur on his projection allow a faithful representation of the shape either of the land masses or of the oceans in the higher latitudes. On the other hand, these interruptions are objectionable in maps to be used for certain purposes; as, for instance, those illustrating world trade (see Illus. B, p. 547).

The Scale

All maps are necessarily smaller than the actual surface areas which they represent. To interpret correctly distances on them, it is essential to know what relation exists between a certain linear distance in the field and the same distance on the map. This relation is called the *scale* of the map. For example, if the distance between two houses is 1 mile, or 63,360 inches, and on the map the symbols for these houses are 1 inch apart, then the scale of the map is 1/63,360 or 1:63,360. The metric system, with its simple relationships between units of measurement, gives the most satisfactory map scales. If the distance between two crossroads is 10 kilometers (a little over six miles), or 1,000,000 centimeters, and this distance is represented on the map by 1 centimeter, then the scale of the map is 1:1,000,000.

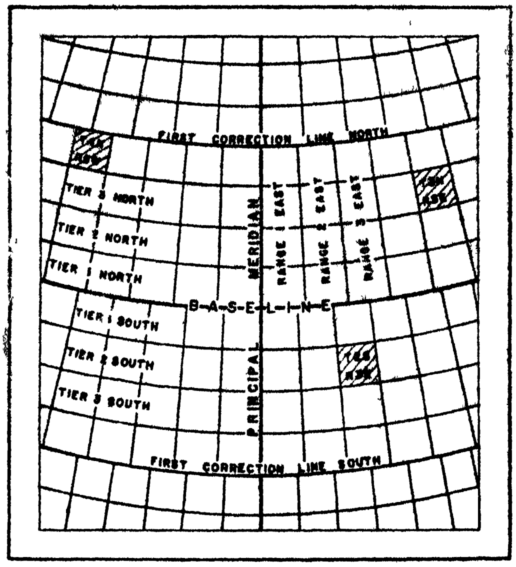
If the ratio expressing the scale of a map is a small value—as 1:10,000,000—we speak of it as a *small-scale map*. If it is large—as 1:2,500—we speak of it as a *large-scale map*. Large-scale maps show relatively small areas of the earth's surface. Small-scale maps, on the other hand may show whole continents, or even the entire earth. The former can show much detail; the latter can show only the major features of the area represented. Most maps in atlases are small-scale maps of continents, parts of continents, countries, and so forth. Such maps are useful for reference purposes and to convey a general idea of the major features of the natural and cultural landscapes.

For practical purposes, large-scale maps giving considerable detail are necessary. Of these, *topographic* maps are perhaps the most important. They are usually made and published by the governments of the various countries. Their scale rarely is smaller than 1:250,000. The uses of such maps are legion; in fact, no civilized country can do without a set of large-scale maps, covering at least all the important sections of the country. Topographic maps give much useful detail about differences in elevation, types of surface, distances, facts of human occupation, and so on. They are useful for military purposes, and they form a necessary basis for detailed geological and soil maps, for the planning of roads, for irrigation and drainage works, and for the solution of many other practical problems. In some countries they are in great demand by tourists. The topographic maps of the United

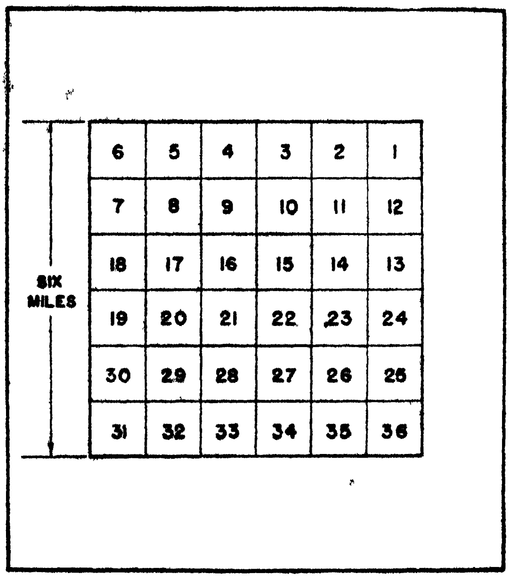
States are published by the Geological Survey at Washington, D. C., and usually they are on a scale of 1:62,500 or 1:125,000 (see Illus. p. 548).

Land Survey Maps in the United States

Maps showing the exact location of real estate, also among the most important large-scale maps, are of prime necessity to organized society. Private ownership would not be possible without the location and delimitation which such devices provide. Such maps are equally important in the assessment of property, in the securing of land mortgages, or in any other transaction in which real estate is involved. The significance of such transactions in the business world should induce all citizens to familiarize themselves with the principles involved in accurate description and representation of the location of definite parcels of land.



(A.) Diagram of principal meridian, baseline, townships, and ranges.



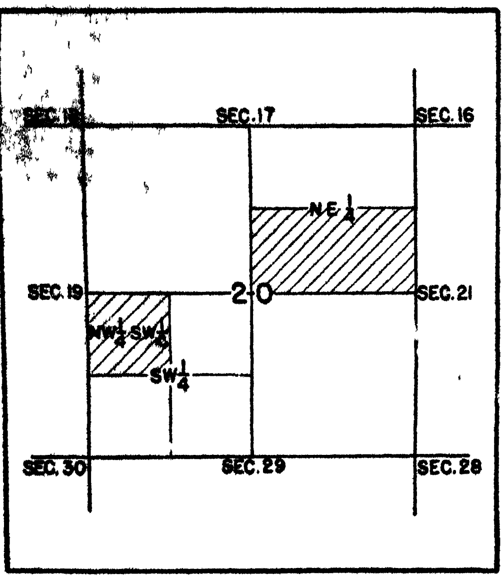
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

(B.) Diagram showing scheme of numbering sections in a township.

Metes and Bounds

The early pioneers brought with them the old European system of location by metes and bounds. To locate an area by this method, landmarks such as trees, streams, rocks, highways, and stakes are selected as points of beginning. Directions are then determined by the magnetic compass, and distances are ascertained by surveyors' chains. These landmarks, however, are not permanent, and even magnetic north is slowly but continually shifting. The confusion and uncertainty associated with this method of land survey early led to dissatisfaction, but any change is difficult when land ownership has once become established under it. That is the reason for the continuance of the metes and bounds system in the older sections along the Atlantic Coast even now. When the new lands west of the Appalachians were acquired as part of the national domain, improved methods of land description were sought and later adopted.

Acts of Congress in 1785, 1796, 1800, and 1805 provided the groundwork for a completely new and more orderly method of surveying for the newer territory to the west. Location on spherical surfaces necessitates a carefully established intersection of a meridian and a parallel as a starting point. Since it was not practicable to refer all surveys to the same meridian and the same parallel, several were



(A.) Diagram of mode of subdivision of a section.

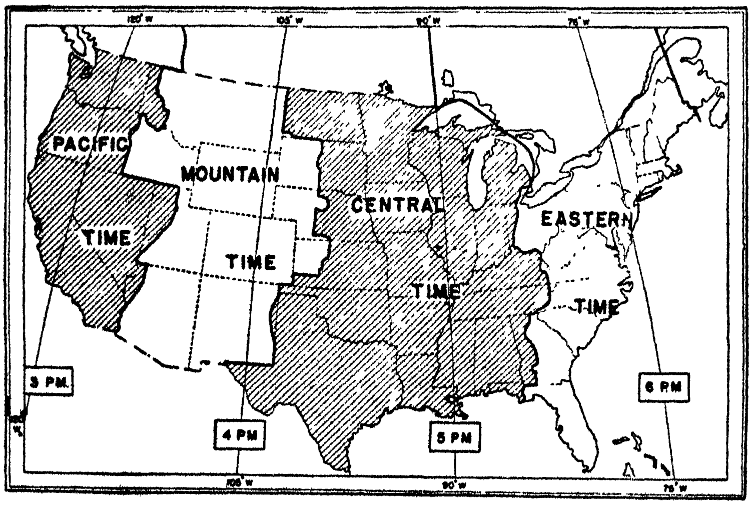
determined and designated as the reference lines for civil land survey districts. These were designated as *principal meridians* and *base lines*, respectively.

Principal Meridians

Principal meridians are run north or south, or both from some initial point which is accurately located by latitude and longitude. About 32 of these principal meridians of varying length have been surveyed at convenient intervals. The first meridian of this nature serves as the boundary line between Indiana and Ohio. The second is west of the center of Indiana. Some of the principal meridians are known by name, others by numbers. The one bisecting the eastern part of Nebraska, for instance, is known as the sixth principal meridian. The Tallahassee principal meridian, on the other hand, runs through the city of that name and is only 23 miles long. North and south strips of land about six miles wide, called *ranges*, are laid off to the east and west of these meridians and are numbered consecutively. Each principal meridian, with its system of ranges, is independent of other like systems.

Base lines, extending east and west, are run through the initial points on the principal meridians. At distances of six miles and multiples thereof from the base line, parallel lines are drawn, forming what is known as "tiers of townships." These are numbered consecutively north or south from the base line.

It will be noticed in illustration A on page 549 that 24 miles north of the base line slight jogs occur east of the principal meridian, to the right, whereas west of it the jogs occur to the left. Although the delimiting meridians are separated by intervals of six miles on the base line, the sphericity of the earth causes them to converge northward. At latitude 40° the convergence is about 6.7 feet per mile, which amounts to more than 40 feet for each town-

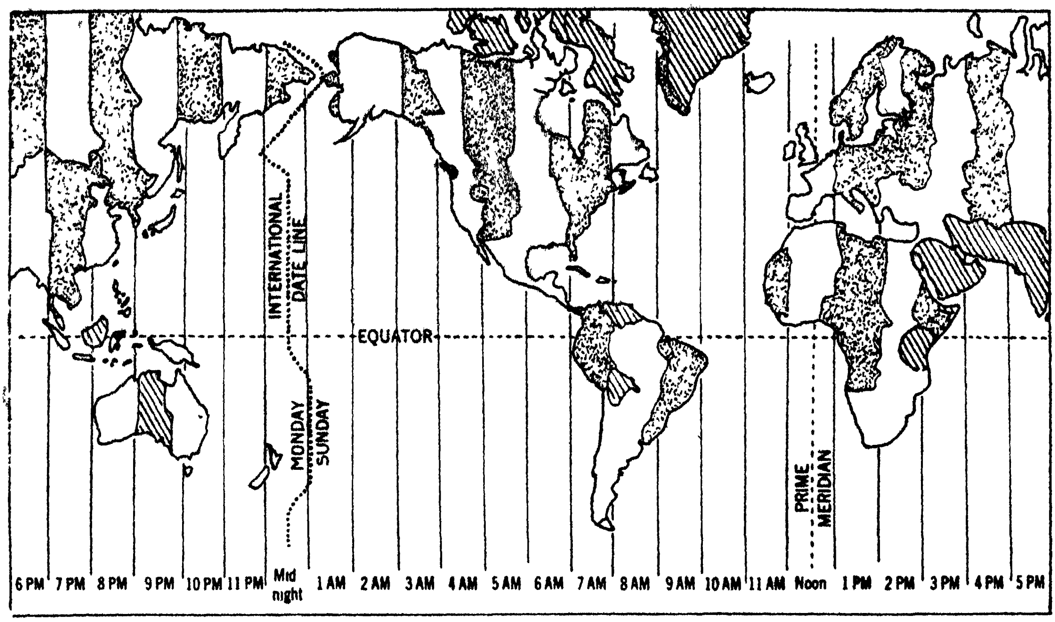


(B.) Standard time belts of the United States.

ship. In order to provide for townships of about equal area, these jogs, known as *correction lines,* are usually arranged at intervals of 24 miles. The enclosed units of land, approximately 36 square miles in each, are known as "congressional townships" as distinguished from the political subdivisions of the county called "civil townships."

In this scheme of land survey, a square mile is known as a section. The usual manner in which sections are numbered and identified in illustration B on page 549.

The subdivision of sections is computed by halves, quarters, and half-quarters. A number of ways in which a section may be subdivided are shown in Illus. A, page 550. The divisions are really simpler than they appear at first glance. The essential fact is that a section of land embraces 640 acres and that portions are designated as definite fractions of this number. Thus, if the description reads S ½ NE ¼ sec. 20, the area is 80 acres; if a description reads NW ¼ SW ¼, only 40 acres are included.



Standard time zones and the International Date Line The figures show the time in each zone when it is noon at Greenwich. The zones are irregular on the land but are even bands over the oceans. Russia runs one hour ahead of standard time in each zone Areas with diagonal lines do not conform to the standard time zone system. From *Physical Geography,* by Albert Seeman, Prentice-Hall, Inc., 1942.

Reckoning of Time

The sun reaches its highest position of the day on any given meridian at exactly the same instant. That instant we call *noon,* and it is upon this that our time system is based. As one goes eastward or westward, the occurrence of the noon instant constantly changes. As a result, local time changes. Toward the east the hour is more advanced, that is, it is later, for the sun has been above the horizon longer; toward the west it is earlier, for the sun has been above the horizon a shorter time. Such differences in time have many practical implications in these days of fast travel, and more especially of fast communication. In foreign trade it is often essential to know exactly what the time is at the client's office, in order to make best use of cable correspondence or for telephone or radio messages.

Standard Time

Prior to 1883 the people of the different cities of the United States generally used the local time of the meridian passing through the city. Since the noon instant was not the same for any two cities of different longitudes, many local time systems were in use. Such a variety of time was disconcerting to the local inhabitants and was confusing to all who traveled extensively. With the increased use of railroad and telegraph, the old system soon fell into disfavor. A standardized time scheme became necessary.

Since the sun crosses 360 degrees of longitude in a period of 24 hours, it crosses a belt 15 degrees longitude in width in one hour. By adopting the noon instant of the middle meridian, the maximum deviation from the true local noon does not exceed 30 minutes anywhere within the belt. This is the basis for the division of the country into standard time belts, and within them the solar time of the central meridian is arbitrarily accepted as the correct time for all places. Thus, in the United States, Eastern Standard Time is based on the meridian of 75° W. longitude, Central Standard Time on the 90° meridian, Rocky Mountain Standard Time on the 105° meridian, and Pacific Standard Time on the 120° meridian. Europe has three time belts, corresponding to our belts of standard time: Western, Central, and Eastern European time. Theoretically, such time belts should be confined strictly within 7½ degrees on either side of the standard meridian. But since population centers recognize no such boundaries, practical adjustments to problems of individual cities and also to transportation problems sometimes make it necessary to set aside strict observance of the theoretical limits. Therefore the boundaries of the time belts are irregular and only approximate the ideal (see Illus. p. 550).

The International Date Line

The previous paragraphs have made clear that around the world different clock hours occur simultaneously. When it is noon at London, it is past noon east of there and before noon west of there. Likewise, when it is midnight at London it is past midnight at places east and before midnight at places west. Thus when Big Ben strikes the midnight hour at London on Saturday night, places to the east have Sunday whereas to the west Saturday still persists.

It is obvious that somewhere on earth every new date must appear first. By international agreement, the 180th meridian has been chosen as the place where each new date first begins (see Illus. p. 551). The International Date Line thus selected makes deviations from the 180th meridian only where land areas are crossed. Thus, every calendar date *first* appears on earth when it is midnight at the International Date Line. Inasmuch as the earth rotates from the west toward the east, the midnight line travels westward from the International Date Line, carrying the new date with it. Thus, just west of the International Date Line the new date appears 24 hours sooner than it occurs just east of the line. For example, when it is Tuesday west of the line it is still Monday east of the line and will so continue until the midnight hour reaches there. Since the new date first arrives just west of the Date Line and then proceeds westward as the earth rotates, a complete rotation, involving 24 hours of time, is necessary to bring the same date to points just east of the line. With the completion of one rotation, Tuesday has been begun over all the earth, and then Wednesday is begun west of the line and the sequence is repeated. It is well to impress firmly upon the mind that every new date first appears on earth when it is midnight at the International Date Line, and that it follows the midnight line around the world from the Date Line westward to Japan, continental Asia, Europe, and thence across the Atlantic to New York, Chicago, San Francisco, and again into the Pacific.

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